

# Package ‘MOFA2’

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**Type** Package

**Title** Multi-Omics Factor Analysis v2

**Version** 1.8.0

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**Description** The MOFA2 package contains a collection of tools for training and analysing multi-omic factor analysis (MOFA). MOFA is a probabilistic factor model that aims to identify principal axes of variation from data sets that can comprise multiple omic layers and/or groups of samples. Additional time or space information on the samples can be incorporated using the MEFISTO framework, which is part of MOFA2. Downstream analysis functions to inspect molecular features underlying each factor, vizualisation, imputation etc are available.

**Encoding** UTF-8

**Depends** R (>= 4.0)

**Imports** rhdf5, dplyr, tidyr, reshape2, pheatmap, ggplot2, methods, RColorBrewer, cowplot, ggrepel, reticulate, HDF5Array, grDevices, stats, magrittr, forcats, utils, corrplot, DelayedArray, Rtsne, uwot, basilisk, stringi

**Suggests** knitr, testthat, Seurat, ggpubr, foreach, psych, MultiAssayExperiment, SummarizedExperiment, SingleCellExperiment, ggrastr, mvtnorm, GGally, rmarkdown, data.table, tidyverse, BiocStyle, Matrix, markdown

**biocViews** DimensionReduction, Bayesian, Visualization

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add\_mofa\_factors\_to\_seurat

*Function to add the MOFA representation onto a Seurat object*

### Description

Function to add the MOFA latent representation to a Seurat object

### Usage

```
add_mofa_factors_to_seurat(
  mofa_object,
  seurat_object,
  views = "all",
  factors = "all"
)
```

### Arguments

|               |  |
|---------------|--|
| mofa_object   | a trained <a href="#">MOFA</a> object.   |
| seurat_object | a Seurat object  |
| views         | character vector with the view names, or numeric vector with view indexes.<br>Default is 'all'         |
| factors       | character vector with the factor names, or numeric vector with the factor indexes.<br>Default is 'all' |

### Details

This function calls the `CreateDimReducObject` function from Seurat to store the MOFA factors.

### Value

Returns a Seurat object with the 'reductions' slot filled with the MOFA factors. Also adds, if calculated, the UMAP/TSNE obtained with the MOFA factors.

### Examples

```
# Generate a simulated data set
MOFAexample <- make_example_data()
```

---

 calculate\_contribution\_scores

*Calculate contribution scores for each view in each sample*


---

### Description

This function calculates, \*for each sample\* how much each view contributes to its location in the latent manifold, what we call *contribution scores*

### Usage

```
calculate_contribution_scores(
  object,
  views = "all",
  groups = "all",
  factors = "all",
  scale = TRUE
)
```

### Arguments

|         |   |
|---------|---|
| object  | a trained <a href="#">MOFA</a> object.  |
| views   | character vector with the view names, or numeric vector with view indexes. Default is 'all'   |
| groups  | character vector with the group names, or numeric vector with group indexes. Default is 'all'   |
| factors | character vector with the factor names, or numeric vector with the factor indexes. Default is 'all'   |
| scale   | logical indicating whether to scale the sample-wise variance explained values by the total amount of variance explained per view. This effectively normalises each view by its total variance explained. It is important when different amounts of variance is explained for each view (check with <code>plot_variance_explained(..., plot_total=TRUE)</code> ) |

### Details

Contribution scores are calculated in three steps:

- Step 1 calculate variance explained for each cell  $i$  and each view  $m$  ( $R_{im}$ ), using all factors
- Step 2 (optional) scale values by the total variance explained for each view
- Step 3 calculate contribution score ( $C_{im}$ ) for cell  $i$  and view  $m$  as:

$$C_{im} = \frac{R_{im}}{\sum_m R_{im}}$$

Note that contribution scores can be calculated using any number of data modalities, but it is easier to interpret when you specify two.

Please note that this functionality is still experimental, contact the authors if you have questions.

**Value**

adds the contribution scores to the metadata slot (`samples_metadata(MOFAobject)`) and to the `MOFAobject@cache` slot

**Examples**

```
# Using an existing trained model on simulated data
file <- system.file("extdata", "model.hdf5", package = "MOFA2")
model <- load_model(file)
model <- calculate_contribution_scores(model)
```

---

`calculate_variance_explained`

*Calculate variance explained by the model*

---

**Description**

This function takes a trained MOFA model as input and calculates the proportion of variance explained (i.e. the coefficient of determinations ( $R^2$ )) by the MOFA factors across the different views.

**Usage**

```
calculate_variance_explained(
  object,
  views = "all",
  groups = "all",
  factors = "all"
)
```

**Arguments**

|                      |   |
|----------------------|---|
| <code>object</code>  | a <a href="#">MOFA</a> object.  |
| <code>views</code>   | character vector with the view names, or numeric vector with view indexes. Default is 'all'         |
| <code>groups</code>  | character vector with the group names, or numeric vector with group indexes. Default is 'all'       |
| <code>factors</code> | character vector with the factor names, or numeric vector with the factor indexes. Default is 'all' |

**Value**

a list with matrices with the amount of variation explained per factor and view.

## Examples

```
# Using an existing trained model on simulated data
file <- system.file("extdata", "model.hdf5", package = "MOFA2")
model <- load_model(file)

# Calculate variance explained (R2)
r2 <- calculate_variance_explained(model)

# Plot variance explained values (view as x-axis, and factor as y-axis)
plot_variance_explained(model, x="view", y="factor")

# Plot variance explained values (view as x-axis, and group as y-axis)
plot_variance_explained(model, x="view", y="group")

# Plot variance explained values for factors 1 to 3
plot_variance_explained(model, x="view", y="group", factors=1:3)

# Scale R2 values
plot_variance_explained(model, max_r2 = 0.25)
```

---

calculate\_variance\_explained\_per\_sample

*Calculate variance explained by the MOFA factors for each sample*

---

## Description

This function takes a trained MOFA model as input and calculates, **for each sample** the proportion of variance explained (i.e. the coefficient of determinations ( $R^2$ )) by the MOFA factors across the different views.

## Usage

```
calculate_variance_explained_per_sample(
  object,
  views = "all",
  groups = "all",
  factors = "all"
)
```

## Arguments

|         |  |
|---------|--|
| object  | a <a href="#">MOFA</a> object.   |
| views   | character vector with the view names, or numeric vector with view indexes.<br>Default is 'all'         |
| groups  | character vector with the group names, or numeric vector with group indexes.<br>Default is 'all'       |
| factors | character vector with the factor names, or numeric vector with the factor indexes.<br>Default is 'all' |

**Value**

a list with matrices with the amount of variation explained per sample and view.

**Examples**

```
# Using an existing trained model on simulated data
file <- system.file("extdata", "model.hdf5", package = "MOFA2")
model <- load_model(file)

# Calculate variance explained (R2)
r2 <- calculate_variance_explained_per_sample(model)
```

---

|                 |  |
|-----------------|--|
| cluster_samples | <i>K-means clustering on samples based on latent factors</i> |
|-----------------|--|

---

**Description**

MOFA factors are continuous in nature but they can be used to predict discrete clusters of samples. The clustering can be performed in a single factor, which is equivalent to setting a manual threshold. More interestingly, it can be done using multiple factors, where multiple sources of variation are aggregated. Importantly, this type of clustering is not weighted and does not take into account the different importance of the latent factors.

**Usage**

```
cluster_samples(object, k, factors = "all", ...)
```

**Arguments**

|         |  |
|---------|--|
| object  | a trained <a href="#">MOFA</a> object.   |
| k       | number of clusters (integer).  |
| factors | character vector with the factor name(s), or numeric vector with the index of the factor(s) to use. Default is 'all' |
| ...     | extra arguments passed to <a href="#">kmeans</a>   |

**Details**

In some cases, due to model technicalities, samples can have missing values in the latent factor space. In such a case, these samples are currently ignored in the clustering procedure.

**Value**

output from [kmeans](#) function



## Examples

```
# Using an existing trained model on simulated data
file <- system.file("extdata", "model.hdf5", package = "MOFA2")
model <- load_model(file)

# Cluster samples in the factor space using factors 1 to 3 and K=2 clusters
clusters <- cluster_samples(model, k=2, factors=1:3)
```

---

|              |   |
|--------------|---|
| compare_elbo | <i>Compare different trained MOFA objects in terms of the final value of the ELBO statistics and number of inferred factors</i> |
|--------------|---|

---

## Description

Different objects of MOFA are compared in terms of the final value of the ELBO statistics. For model selection the model with the highest ELBO value is selected.

## Usage

```
compare_elbo(models, log = FALSE, return_data = FALSE)
```

## Arguments

|             |  |
|-------------|--|
| models      | a list containing MOFA objects.  |
| log         | logical indicating whether to plot the log of the ELBO.                          |
| return_data | logical indicating whether to return a data.frame with the ELBO values per model |

## Value

A [ggplot](#) object or the underlying data.frame if return\_data is TRUE

## Examples

```
# Using an existing trained model on simulated data
file <- system.file("extdata", "model.hdf5", package = "MOFA2")
model1 <- load_model(file)
model2 <- load_model(file)

# Compare ELBO between models
## Not run: compare_elbo(list(model1,model2))
```

---

|                 |   |
|-----------------|---|
| compare_factors | <i>Plot the correlation of factors between different models</i> |
|-----------------|---|

---

### Description

Different MOFA objects are compared in terms of correlation between their factors.

### Usage

```
compare_factors(models, ...)
```

### Arguments

|        |                                    |
|--------|------------------------------------|
| models | a list with MOFA objects.          |
| ...    | extra arguments passed to pheatmap |

### Details

If assessing model robustness across trials, the output should look like a block diagonal matrix, suggesting that all factors are robustly detected in all model instances.

### Value

Plots a heatmap of the Pearson correlation between latent factors across all input models.

### Examples

```
# Using an existing trained model on simulated data
file <- system.file("extdata", "model.hdf5", package = "MOFA2")
model1 <- load_model(file)
model2 <- load_model(file)

# Compare factors between models
compare_factors(list(model1,model2))
```

---

|                                   |   |
|-----------------------------------|---|
| correlate_factors_with_covariates | <i>Plot correlation of factors with external covariates</i> |
|-----------------------------------|---|

---

### Description

Function to correlate factor values with external covariates.

**Usage**

```

correlate_factors_with_covariates(
  object,
  covariates,
  factors = "all",
  groups = "all",
  abs = FALSE,
  plot = c("log_pval", "r"),
  alpha = 0.05,
  return_data = FALSE,
  transpose = FALSE,
  ...
)

```

**Arguments**

|             |   |
|-------------|---|
| object      | a trained <a href="#">MOFA</a> object.  |
| covariates  | <ul style="list-style-type: none"> <li>• <b>data.frame</b>: a data.frame where the samples are stored in the rows and the covariates are stored in the columns. Use row names for sample names and column names for covariate names. Columns values must be numeric.</li> <li>• <b>character vector</b>: character vector with names of columns that are present in the sample metadata (<code>samples_metadata(model)</code>)</li> </ul> |
| factors     | character vector with the factor name(s), or numeric vector with the index of the factor(s) to use. Default is 'all'.   |
| groups      | character vector with the groups names, or numeric vector with the indices of the groups of samples to use, or "all" to use samples from all groups.  |
| abs         | logical indicating whether to take the absolute value of the correlation coefficient (default is TRUE).   |
| plot        | character indicating whether to plot Pearson correlation coefficients ( <code>plot="r"</code> ) or log10 adjusted p-values ( <code>plot="log_pval"</code> ).  |
| alpha       | p-value threshold   |
| return_data | logical indicating whether to return the correlation results instead of plotting  |
| transpose   | logical indicating whether to transpose the plot  |
| ...         | extra arguments passed to <a href="#">corrplot</a> (if <code>plot=="r"</code> ) or <a href="#">pheatmap</a> (if <code>plot=="log_pval"</code> ).  |

**Value**

A [corrplot](#) (if `plot=="r"`) or [pheatmap](#) (if `plot=="log_pval"`) or the underlying data.frame if `return_data` is TRUE

---

|                  |   |
|------------------|---|
| covariates_names | <i>covariates_names: set and retrieve covariate names</i> |
|------------------|---|

---

### Description

covariates\_names: set and retrieve covariate names

### Usage

```
covariates_names(object)

covariates_names(object) <- value

## S4 method for signature 'MOFA'
covariates_names(object)

## S4 replacement method for signature 'MOFA,vector'
covariates_names(object) <- value
```

### Arguments

|        |                                       |
|--------|---------------------------------------|
| object | a <a href="#">MOFA</a> object.        |
| value  | a character vector of covariate names |

### Value

character vector with the covariate names

### Examples

```
# Using an existing trained model on simulated data
file <- system.file("extdata", "MEFISTO_model.hdf5", package = "MOFA2")
model <- load_model(file)
covariates_names(model)
```

---

|             |                             |
|-------------|-----------------------------|
| create_mofa | <i>create a MOFA object</i> |
|-------------|-----------------------------|

---

### Description

Method to create a [MOFA](#) object. Depending on the input data format, this method calls one of the following functions:

- **long data.frame:** [create\\_mofa\\_from\\_df](#)
- **List of matrices:** [create\\_mofa\\_from\\_matrix](#)

- **MultiAssayExperiment:** [create\\_mofa\\_from\\_MultiAssayExperiment](#)
- **Seurat:** [create\\_mofa\\_from\\_Seurat](#)
- **SingleCellExperiment:** [create\\_mofa\\_from\\_SingleCellExperiment](#)

Please read the documentation of the corresponding function for more details on your specific data format.

### Usage

```
create_mofa(data, groups = NULL, extract_metadata = TRUE, ...)
```

### Arguments

|                  |   |
|------------------|---|
| data             | one of the formats above  |
| groups           | group information, only relevant when using the multi-group framework.  |
| extract_metadata | logical indicating whether to incorporate the sample metadata from the input object into the MOFA object ( not relevant when the input is a list of matrices). Default is TRUE. |
| ...              | further arguments that can be passed to the function depending on the input data format. See the documentation of above functions for details.                                  |

### Value

Returns an untrained [MOFA](#) object

### Examples

```
# Using an existing simulated data with two groups and two views
file <- system.file("extdata", "test_data.RData", package = "MOFA2")

# Load data (in long data.frame format)
load(file)
MOFAmodel <- create_mofa(dt)
```

---

`create_mofa_from_df`     *create a MOFA object from a data.frame object*

---

### Description

Method to create a [MOFA](#) object from a data.frame object

### Usage

```
create_mofa_from_df(df, extract_metadata = TRUE)
```

**Arguments**

`df` data.frame object with at most 5 columns: sample, group, feature, view, value. The group column (optional) indicates the group of each sample when using the multi-group framework. The view column (optional) indicates the view of each feature when having multi-view data.

`extract_metadata` logical indicating whether to incorporate the extra columns as sample metadata into the MOFA object

**Value**

Returns an untrained MOFA object

**Examples**

```
# Using an existing simulated data with two groups and two views
file <- system.file("extdata", "test_data.RData", package = "MOFA2")

# Load data (in long data.frame format)
load(file)
MOFAmodel <- create_mofa_from_df(dt)
```

---

create\_mofa\_from\_matrix

*create a MOFA object from a list of matrices*

---

**Description**

Method to create a MOFA object from a list of matrices

**Usage**

```
create_mofa_from_matrix(data, groups = NULL)
```

**Arguments**

`data` A list of matrices, where each entry corresponds to one view. Samples are stored in columns and features in rows. Missing values must be filled in prior to creating the MOFA object (see for example the CLL tutorial)

`groups` A character vector with group assignment for every sample. Default is NULL, no group structure.

**Value**

Returns an untrained MOFA object

**Examples**

```
m <- make_example_data()
create_mofa_from_matrix(m$data)
```

---

```
create_mofa_from_MultiAssayExperiment
  create a MOFA object from a MultiAssayExperiment object
```

---

**Description**

Method to create a [MOFA](#) object from a `MultiAssayExperiment` object

**Usage**

```
create_mofa_from_MultiAssayExperiment(
  mae,
  groups = NULL,
  extract_metadata = FALSE
)
```

**Arguments**

|                               |   |
|-------------------------------|---|
| <code>mae</code>              | a <code>MultiAssayExperiment</code> object  |
| <code>groups</code>           | a string specifying column name of the <code>colData</code> to use it as a group variable. Alternatively, a character vector with group assignment for every sample. Default is <code>NULL</code> (no group structure). |
| <code>extract_metadata</code> | logical indicating whether to incorporate the metadata from the <code>MultiAssayExperiment</code> object into the <code>MOFA</code> object  |

**Value**

Returns an untrained [MOFA](#) object

---

```
create_mofa_from_Seurat
  create a MOFA object from a Seurat object
```

---

**Description**

Method to create a [MOFA](#) object from a `Seurat` object

**Usage**

```
create_mofa_from_Seurat(  
  seurat,  
  groups = NULL,  
  assays = NULL,  
  slot = "scale.data",  
  features = NULL,  
  extract_metadata = FALSE  
)
```

**Arguments**

|                  |  |
|------------------|--|
| seurat           | Seurat object  |
| groups           | a string specifying column name of the samples metadata to use it as a group variable. Alternatively, a character vector with group assignment for every sample. Default is NULL (no group structure). |
| assays           | assays to use, default is NULL, it fetched all assays available  |
| slot             | assay slot to be used (default is scale.data).   |
| features         | a list with vectors, which are used to subset features, with names corresponding to assays; a vector can be provided when only one assay is used   |
| extract_metadata | logical indicating whether to incorporate the metadata from the Seurat object into the MOFA object   |

**Value**

Returns an untrained [MOFA](#) object

---

create\_mofa\_from\_SingleCellExperiment

*create a MOFA object from a SingleCellExperiment object*

---

**Description**

Method to create a [MOFA](#) object from a SingleCellExperiment object

**Usage**

```
create_mofa_from_SingleCellExperiment(  
  sce,  
  groups = NULL,  
  assay = "logcounts",  
  extract_metadata = FALSE  
)
```



**Arguments**

|                  |   |
|------------------|---|
| sce              | SingleCellExperiment object   |
| groups           | a string specifying column name of the colData to use it as a group variable. Alternatively, a character vector with group assignment for every sample. Default is NULL (no group structure). |
| assay            | assay to use, default is logcounts.   |
| extract_metadata | logical indicating whether to incorporate the metadata from the SingleCellExperiment object into the MOFA object  |

**Value**

Returns an untrained [MOFA](#) object

---

|               |   |
|---------------|---|
| factors_names | <i>factors_names: set and retrieve factor names</i> |
|---------------|---|

---

**Description**

factors\_names: set and retrieve factor names

**Usage**

```
factors_names(object)

factors_names(object) <- value

## S4 method for signature 'MOFA'
factors_names(object)

## S4 replacement method for signature 'MOFA,vector'
factors_names(object) <- value
```

**Arguments**

|        |                                    |
|--------|------------------------------------|
| object | a <a href="#">MOFA</a> object.     |
| value  | a character vector of factor names |

**Value**

character vector with the factor names

**Examples**

```
# Using an existing trained model on simulated data
file <- system.file("extdata", "model.hdf5", package = "MOFA2")
model <- load_model(file)
factors_names(model)
```

---

features\_metadata      *features\_metadata: set and retrieve feature metadata*

---

### Description

features\_metadata: set and retrieve feature metadata

### Usage

```
features_metadata(object)

features_metadata(object) <- value

## S4 method for signature 'MOFA'
features_metadata(object)

## S4 replacement method for signature 'MOFA,data.frame'
features_metadata(object) <- value
```

### Arguments

|        |  |
|--------|--|
| object | a <a href="#">MOFA</a> object.   |
| value  | data frame with feature information, it at least must contain the columns feature and view |

### Value

a data frame with sample metadata

### Examples

```
# Using an existing trained model on simulated data
file <- system.file("extdata", "model.hdf5", package = "MOFA2")
model <- load_model(file)
features_metadata(model)
```

---

features\_names      *features\_names: set and retrieve feature names*

---

### Description

features\_names: set and retrieve feature names

**Usage**

```
features_names(object)

features_names(object) <- value

## S4 method for signature 'MOFA'
features_names(object)

## S4 replacement method for signature 'MOFA,list'
features_names(object) <- value
```

**Arguments**

`object` a [MOFA](#) object.

`value` list of character vectors with the feature names for every view

**Value**

list of character vectors with the feature names for each view

**Examples**

```
# Using an existing trained model on simulated data
file <- system.file("extdata", "model.hdf5", package = "MOFA2")
model <- load_model(file)
features_names(model)
```

---

|                |                              |
|----------------|------------------------------|
| get_covariates | <i>Get sample covariates</i> |
|----------------|------------------------------|

---

**Description**

Function to extract the covariates from a [MOFA](#) object using MEFISTO.

**Usage**

```
get_covariates(
  object,
  covariates = "all",
  as.data.frame = FALSE,
  warped = FALSE
)
```

**Arguments**

|               |  |
|---------------|--|
| object        | a <a href="#">MOFA</a> object.   |
| covariates    | character vector with the covariate name(s), or numeric vector with the covariate index(es). |
| as.data.frame | logical indicating whether to output the result as a long data frame, default is FALSE.      |
| warped        | logical indicating whether to extract the aligned covariates                                 |

**Value**

a matrix with dimensions (samples,covariates). If `as.data.frame` is TRUE, a long-formatted data frame with columns (sample,factor,value)

**Examples**

```
# Using an existing trained model
file <- system.file("extdata", "MEFISTO_model.hdf5", package = "MOFA2")
model <- load_model(file)
covariates <- get_covariates(model)
```

---

get\_data

*Get data*


---

**Description**

Fetch the input data

**Usage**

```
get_data(
  object,
  views = "all",
  groups = "all",
  features = "all",
  as.data.frame = FALSE,
  add_intercept = TRUE,
  denoise = FALSE,
  na.rm = TRUE
)
```

**Arguments**

|        |  |
|--------|--|
| object | a <a href="#">MOFA</a> object.   |
| views  | character vector with the view name(s), or numeric vector with the view index(es). Default is "all". |

|               |  |
|---------------|--|
| groups        | character vector with the group name(s), or numeric vector with the group index(es). Default is "all".                                       |
| features      | a *named* list of character vectors. Example: list("view1"=c("feature_1","feature_2"), "view2"=c("feature_3","feature_4")) Default is "all". |
| as.data.frame | logical indicating whether to return a long data frame instead of a list of matrices. Default is FALSE.                                      |
| add_intercept | logical indicating whether to add feature intercepts to the data. Default is TRUE.   |
| denoise       | logical indicating whether to return the denoised data (i.e. the model predictions). Default is FALSE.                                       |
| na.rm         | remove NAs from the data.frame (only if as.data.frame is TRUE).  |

### Details

By default this function returns a list where each element is a data matrix with dimensionality (D,N) where D is the number of features and N is the number of samples.

Alternatively, if `as.data.frame` is TRUE, the function returns a long-formatted data frame with columns (view,feature,sample,value). Missing values are not included in the the long data.frame format by default. To include them use the argument `na.rm=FALSE`.

### Value

A list of data matrices with dimensionality (D,N) or a data.frame (if `as.data.frame` is TRUE)

### Examples

```
# Using an existing trained model on simulated data
file <- system.file("extdata", "model.hdf5", package = "MOFA2")
model <- load_model(file)

# Fetch data
data <- get_data(model)

# Fetch a specific view
data <- get_data(model, views = "view_0")

# Fetch data in data.frame format instead of matrix format
data <- get_data(model, as.data.frame = TRUE)

# Fetch centered data (do not add the feature intercepts)
data <- get_data(model, as.data.frame = FALSE)

# Fetch denoised data (do not add the feature intercepts)
data <- get_data(model, denoise = TRUE)
```

---

`get_default_data_options`*Get default data options*

---

### Description

Function to obtain the default data options.

### Usage

```
get_default_data_options(object)
```

### Arguments

`object`            an untrained [MOFA](#) object

### Details

This function provides a default set of data options that can be modified and passed to the [MOFA](#) object in the [prepare\\_mofa](#) step (see example), i.e. after creating a [MOFA](#) object (using [create\\_mofa](#)) and before starting the training (using [run\\_mofa](#)) The data options are the following:

- **scale\_views**: logical indicating whether to scale views to have the same unit variance. As long as the scale differences between the views is not too high, this is not required. Default is FALSE.
- **scale\_groups**: logical indicating whether to scale groups to have the same unit variance. As long as the scale differences between the groups is not too high, this is not required. Default is FALSE.
- **use\_float32**: logical indicating whether use float32 instead of float64 arrays to increase speed and memory usage. Default is FALSE.

### Value

Returns a list with the default data options.

### Examples

```
# Using an existing simulated data with two groups and two views
file <- system.file("extdata", "test_data.RData", package = "MOFA2")

# Load data dt (in data.frame format)
load(file)

# Create the MOFA object
MOFAmodel <- create_mofa(dt)

# Load default data options
```

```
data_opts <- get_default_data_options(MOFAModel)

# Edit some of the data options
data_opts$scale_views <- TRUE

# Prepare the MOFA object
MOFAModel <- prepare_mofa(MOFAModel, data_options = data_opts)
```

---

```
get_default_mefisto_options
```

*Get default options for MEFISTO covariates*

---

## Description

Function to obtain the default options for the usage of MEFISTO covariates with MEFISTO

## Usage

```
get_default_mefisto_options(object)
```

## Arguments

object            an untrained [MOFA](#) object

## Details

The options are the following:

- **scale\_cov**: logical: Scale covariates?
- **start\_opt**: integer: First iteration to start the optimisation of GP hyperparameters
- **n\_grid**: integer: Number of points for the grid search in the optimisation of GP hyperparameters
- **opt\_freq**: integer: Frequency of optimisation of GP hyperparameters
- **sparseGP**: logical: Use sparse GPs to speed up the optimisation of the GP parameters?
- **frac\_inducing**: numeric between 0 and 1: Fraction of samples to use as inducing points (only relevant if sparseGP is TRUE)
- **warping**: logical: Activate warping functionality to align covariates between groups (requires a multi-group design)
- **warping\_freq**: numeric: frequency of the warping (only relevant if warping is TRUE)
- **warping\_ref**: A character specifying the reference group for warping (only relevant if warping is TRUE)
- **warping\_open\_begin**: logical: Warping: Allow for open beginning? (only relevant warping is TRUE)
- **warping\_open\_end**: logical: Warping: Allow for open end? (only relevant warping is TRUE)

- **warping\_groups**: Assignment of groups to classes used for alignment (advanced option). Needs to be a vector of length number of samples, e.g. a column of samples\_metadata, which needs to have the same value within each group. By default groups are used specified in 'create\_mofa'.
- **model\_groups**: logical: Model covariance structure across groups (for more than one group, otherwise FALSE)? If FALSE, we assume the same patterns in all groups.
- **new\_values**: Values for which to predict the factor values (for interpolation / extrapolation). This should be numeric matrix in the same format with covariate(s) in rows and new values in columns. Default is NULL, leading to no interpolation.

### Value

Returns a list with default options for the MEFISTO covariate(s) functionality.

### Examples

```
# generate example data
dd <- make_example_data(sample_cov = seq(0,1,length.out = 200), n_samples = 200,
n_factors = 4, n_features = 200, n_views = 4, lscales = c(0.5, 0.2, 0, 0))
# input data
data <- dd$data
# covariate matrix with samples in columns
time <- dd$sample_cov
rownames(time) <- "time"

# create mofa and set covariates
sm <- create_mofa(data = dd$data)
sm <- set_covariates(sm, covariates = time)

MEFISTO_opt <- get_default_mefisto_options(sm)
```

---

```
get_default_model_options
```

*Get default model options*

---

### Description

Function to obtain the default model options.

### Usage

```
get_default_model_options(object)
```

### Arguments

object            an untrained [MOFA](#) object



## Details

This function provides a default set of model options that can be modified and passed to the MOFA object in the `prepare_mofa` step (see example), i.e. after creating a MOFA object (using `create_mofa`) and before starting the training (using `run_mofa`) The model options are the following:

- **likelihoods**: character vector with data likelihoods per view: 'gaussian' for continuous data (Default for all views), 'bernoulli' for binary data and 'poisson' for count data.
- **num\_factors**: numeric value indicating the (initial) number of factors. Default is 15.
- **spikeslab\_factors**: logical indicating whether to use spike and slab sparsity on the factors (Default is FALSE)
- **spikeslab\_weights**: logical indicating whether to use spike and slab sparsity on the weights (Default is TRUE)
- **ard\_factors**: logical indicating whether to use ARD sparsity on the factors (Default is TRUE only if using multiple groups)
- **ard\_weights**: logical indicating whether to use ARD sparsity on the weights (Default is TRUE)

## Value

Returns a list with the default model options.

## Examples

```
# Using an existing simulated data with two groups and two views
file <- system.file("extdata", "test_data.RData", package = "MOFA2")

# Load data dt (in data.frame format)
load(file)

# Create the MOFA object
MOFAmodel <- create_mofa(dt)

# Load default model options
model_opts <- get_default_model_options(MOFAmodel)

# Edit some of the model options
model_opts$num_factors <- 10
model_opts$spikeslab_weights <- FALSE

# Prepare the MOFA object
MOFAmodel <- prepare_mofa(MOFAmodel, model_options = model_opts)
```

---

```
get_default_stochastic_options
  Get default stochastic options
```

---

## Description

Function to obtain the default options for stochastic variational inference.

## Usage

```
get_default_stochastic_options(object)
```

## Arguments

object            an untrained [MOFA](#)

## Details

This function provides a default set of stochastic inference options that can be modified and passed to the [MOFA](#) object in the [prepare\\_mofa](#) step), i.e. after creating a [MOFA](#) object (using [create\\_mofa](#)) and before starting the training (using [run\\_mofa](#)) These options are only relevant when activating stochastic inference in [training\\_options](#) (see example). The stochastic inference options are the following:

- **batch\_size**: numeric value indicating the batch size (as a fraction). Default is 0.5 (half of the data set).
- **learning\_rate**: numeric value indicating the learning rate. Default is 1.0
- **forgetting\_rate**: numeric indicating the forgetting rate. Default is 0.5
- **start\_stochastic**: integer indicating the first iteration to start stochastic inference Default is 1

## Value

Returns a list with default options

## Examples

```
# Using an existing simulated data with two groups and two views
file <- system.file("extdata", "test_data.RData", package = "MOFA2")

# Load data dt (in data.frame format)
load(file)

# Create the MOFA object
MOFAmodel <- create_mofa(dt)

# activate stochastic inference in training options
train_opts <- get_default_training_options(MOFAmodel)
```

```
train_opts$stochastic <- TRUE

# Load default stochastic options
stochastic_opts <- get_default_stochastic_options(MOFAModel)

# Edit some of the stochastic options
stochastic_opts$learning_rate <- 0.75
stochastic_opts$batch_size <- 0.25

# Prepare the MOFA object
MOFAModel <- prepare_mofa(MOFAModel,
  training_options = train_opts,
  stochastic_options = stochastic_opts
)
```

---

```
get_default_training_options
```

*Get default training options*

---

## Description

Function to obtain the default training options.

## Usage

```
get_default_training_options(object)
```

## Arguments

object            an untrained [MOFA](#)

## Details

This function provides a default set of training options that can be modified and passed to the [MOFA](#) object in the [prepare\\_mofa](#) step (see example), i.e. after creating a [MOFA](#) object (using [create\\_mofa](#)) and before starting the training (using [run\\_mofa](#)) The training options are the following:

- **maxiter**: numeric value indicating the maximum number of iterations. Default is 1000. Convergence is assessed using the ELBO statistic.
- **drop\_factor\_threshold**: numeric indicating the threshold on fraction of variance explained to consider a factor inactive and drop it from the model. For example, a value of 0.01 implies that factors explaining less than 1% of variance (in each view) will be dropped. Default is -1 (no dropping of factors)
- **convergence\_mode**: character indicating the convergence criteria, either "fast", "medium" or "slow", corresponding to 0.0005%, 0.00005% or 0.000005% deltaELBO change.

- **verbose**: logical indicating whether to generate a verbose output.
- **startELBO**: integer indicating the first iteration to compute the ELBO (default is 1).
- **freqELBO**: integer indicating the first iteration to compute the ELBO (default is 1).
- **stochastic**: logical indicating whether to use stochastic variational inference (only required for very big data sets, default is FALSE).
- **gpu\_mode**: logical indicating whether to use GPUs (see details).
- **seed**: numeric indicating the seed for reproducibility (default is 42).

### Value

Returns a list with default training options

### Examples

```
# Using an existing simulated data with two groups and two views
file <- system.file("extdata", "test_data.RData", package = "MOFA2")

# Load data dt (in data.frame format)
load(file)

# Create the MOFA object
MOFAmodel <- create_mofa(dt)

# Load default training options
train_opts <- get_default_training_options(MOFAmodel)

# Edit some of the training options
train_opts$convergence_mode <- "medium"
train_opts$startELBO <- 100
train_opts$seed <- 42

# Prepare the MOFA object
MOFAmodel <- prepare_mofa(MOFAmodel, training_options = train_opts)
```

---

get\_dimensions

*Get dimensions*

---

### Description

Extract dimensionalities from the model.

### Usage

```
get_dimensions(object)
```

### Arguments

object            a [MOFA](#) object.

**Details**

K indicates the number of factors, M indicates the number of views, D indicates the number of features (per view), N indicates the number of samples (per group) and C indicates the number of covariates.

**Value**

list containing the dimensionalities of the model

**Examples**

```
# Using an existing trained model
file <- system.file("extdata", "model.hdf5", package = "MOFA2")
model <- load_model(file)
dims <- get_dimensions(model)
```

---

get\_elbo

*Get ELBO*

---

**Description**

Extract the value of the ELBO statistics after model training. This can be useful for model selection.

**Usage**

```
get_elbo(object)
```

**Arguments**

object            a [MOFA](#) object.

**Details**

This can be useful for model selection.

**Value**

Value of the ELBO

**Examples**

```
# Using an existing trained model
file <- system.file("extdata", "model.hdf5", package = "MOFA2")
model <- load_model(file)
elbo <- get_elbo(model)
```

---

|                  |                         |
|------------------|-------------------------|
| get_expectations | <i>Get expectations</i> |
|------------------|-------------------------|

---

### Description

Function to extract the expectations from the (variational) posterior distributions of a trained [MOFA](#) object.

### Usage

```
get_expectations(object, variable, as.data.frame = FALSE)
```

### Arguments

|               |   |
|---------------|---|
| object        | a trained <a href="#">MOFA</a> object.  |
| variable      | variable name: 'Z' for factors and 'W' for weights.                                     |
| as.data.frame | logical indicating whether to output the result as a long data frame, default is FALSE. |

### Details

Technical note: MOFA is a Bayesian model where each variable has a prior distribution and a posterior distribution. In particular, to achieve scalability we used the variational inference framework, thus true posterior distributions are replaced by approximated variational distributions. This function extracts the expectations of the variational distributions, which can be used as final point estimates to analyse the results of the model.

The priors and variational distributions of each variable are extensively described in the supplementary methods of the original paper.

### Value

the output varies depending on the variable of interest:

- "Z" a matrix with dimensions (samples,factors). If `as.data.frame` is TRUE, a long-formatted data frame with columns (sample,factor,value)
- "W" a list of length (views) where each element is a matrix with dimensions (features,factors). If `as.data.frame` is TRUE, a long-formatted data frame with columns (view,feature,factor,value)

### Examples

```
# Using an existing trained model
file <- system.file("extdata", "model.hdf5", package = "MOFA2")
model <- load_model(file)
factors <- get_expectations(model, "Z")
weights <- get_expectations(model, "W")
```

---

|             |                    |
|-------------|--------------------|
| get_factors | <i>Get factors</i> |
|-------------|--------------------|

---

## Description

Extract the latent factors from the model.

## Usage

```
get_factors(  
  object,  
  groups = "all",  
  factors = "all",  
  scale = FALSE,  
  as.data.frame = FALSE  
)
```

## Arguments

|               |  |
|---------------|--|
| object        | a trained <a href="#">MOFA</a> object.   |
| groups        | character vector with the group name(s), or numeric vector with the group index(es). Default is "all".   |
| factors       | character vector with the factor name(s), or numeric vector with the factor index(es). Default is "all". |
| scale         | logical indicating whether to scale factor values.   |
| as.data.frame | logical indicating whether to return a long data frame instead of a matrix. Default is FALSE.            |

## Value

By default it returns the latent factor matrix of dimensionality (N,K), where N is number of samples and K is number of factors.

Alternatively, if `as.data.frame` is TRUE, returns a long-formatted data frame with columns (sample,factor,value).

## Examples

```
# Using an existing trained model on simulated data  
file <- system.file("extdata", "model.hdf5", package = "MOFA2")  
model <- load_model(file)  
  
# Fetch factors in matrix format (a list, one matrix per group)  
factors <- get_factors(model)  
  
# Concatenate groups  
factors <- do.call("rbind", factors)
```

```
# Fetch factors in data.frame format instead of matrix format
factors <- get_factors(model, as.data.frame = TRUE)
```

---

get\_group\_kernel      *Get group covariance matrix*

---

### Description

Extract the inferred group-group covariance matrix per factor

### Usage

```
get_group_kernel(object)
```

### Arguments

object      a [MOFA](#) object.

### Details

This can be used only if covariates are passed to the MOFAobject upon creation and GP\_factors is set to True.

### Value

A list of group-group correlation matrices per factor

---

get\_imputed\_data      *Get imputed data*

---

### Description

Function to get the imputed data. It requires the previous use of the [impute](#) method.

### Usage

```
get_imputed_data(
  object,
  views = "all",
  groups = "all",
  features = "all",
  as.data.frame = FALSE
)
```



**Arguments**

|               |   |
|---------------|---|
| object        | a trained <a href="#">MOFA</a> object.  |
| views         | character vector with the view name(s), or numeric vector with the view index(es). Default is "all".                    |
| groups        | character vector with the group name(s), or numeric vector with the group index(es). Default is "all".                  |
| features      | list of character vectors with the feature names or list of numeric vectors with the feature indices. Default is "all". |
| as.data.frame | logical indicating whether to return a long-formatted data frame instead of a list of matrices. Default is FALSE.       |

**Details**

Data is imputed from the generative model of MOFA.

**Value**

A list containing the imputed values or a data.frame if as.data.frame is TRUE

**Examples**

```
# Using an existing trained model
file <- system.file("extdata", "model.hdf5", package = "MOFA2")
model <- load_model(file)
model <- impute(model)
imputed <- get_imputed_data(model)
```

---

```
get_interpolated_factors
```

*Get interpolated factor values*

---

**Description**

Extract the interpolated factor values

**Usage**

```
get_interpolated_factors(object, as.data.frame = FALSE, only_mean = FALSE)
```

**Arguments**

|               |  |
|---------------|--|
| object        | a <a href="#">MOFA</a> object                                      |
| as.data.frame | logical indicating whether to return data as a data.frame          |
| only_mean     | logical indicating whether include only mean or also uncertainties |

**Details**

This can be used only if covariates are passed to the object upon creation, GP\_factors is set to True and new covariates were passed for interpolation.

**Value**

By default, a nested list containing for each group a list with a matrix with the interpolated factor values ("mean"), their variance ("variance") and the values of the covariate at which interpolation took place ("new\_values"). Alternatively, if as .data.frame is TRUE, returns a long-formatted data frame with columns containing the covariates and (factor, group, mean and variance).

---

|                  |                         |
|------------------|-------------------------|
| get_lengthscales | <i>Get lengthscales</i> |
|------------------|-------------------------|

---

**Description**

Extract the inferred lengthscale for each factor after model training.

**Usage**

```
get_lengthscales(object)
```

**Arguments**

object            a [MOFA](#) object.

**Details**

This can be used only if covariates are passed to the MOFAobject upon creation and GP\_factors is set to True.

**Value**

A numeric vector containing the lengthscale for each factor.

**Examples**

```
# Using an existing trained model
file <- system.file("extdata", "MEFISTO_model.hdf5", package = "MOFA2")
model <- load_model(file)
ls <- get_lengthscales(model)
```

---

`get_scales`*Get scales*

---

**Description**

Extract the inferred scale for each factor after model training.

**Usage**

```
get_scales(object)
```

**Arguments**

`object` a MOFA object.

**Details**

This can be used only if covariates are passed to the MOFAobject upon creation and GP\_factors is set to True.

**Value**

A numeric vector containing the scale for each factor.

**Examples**

```
# Using an existing trained model
file <- system.file("extdata", "MEFISTO_model.hdf5", package = "MOFA2")
model <- load_model(file)
s <- get_scales(model)
```

---

`get_variance_explained`*Get variance explained values*

---

**Description**

Extract the latent factors from the model.

**Usage**

```
get_variance_explained(
  object,
  groups = "all",
  views = "all",
  factors = "all",
  as.data.frame = FALSE
)
```

**Arguments**

|               |  |
|---------------|--|
| object        | a trained MOFA object.   |
| groups        | character vector with the group name(s), or numeric vector with the group index(es). Default is "all".   |
| views         | character vector with the view name(s), or numeric vector with the view index(es). Default is "all".     |
| factors       | character vector with the factor name(s), or numeric vector with the factor index(es). Default is "all". |
| as.data.frame | logical indicating whether to return a long data frame instead of a matrix. Default is FALSE.            |

**Value**

A list of data matrices with variance explained per group or a data.frame (if as.data.frame is TRUE)

**Examples**

```
# Using an existing trained model
file <- system.file("extdata", "model.hdf5", package = "MOFA2")
model <- load_model(file)

# Fetch variance explained values (in matrix format)
r2 <- get_variance_explained(model)

# Fetch variance explained values (in data.frame format)
r2 <- get_variance_explained(model, as.data.frame = TRUE)
```

---

get\_weights

*Get weights*

---

**Description**

Extract the weights from the model.

**Usage**

```
get_weights(
  object,
  views = "all",
  factors = "all",
  abs = FALSE,
  scale = FALSE,
  as.data.frame = FALSE
)
```

**Arguments**

|               |  |
|---------------|--|
| object        | a trained <a href="#">MOFA</a> object.   |
| views         | character vector with the view name(s), or numeric vector with the view index(es). Default is "all".       |
| factors       | character vector with the factor name(s) or numeric vector with the factor index(es).<br>Default is "all". |
| abs           | logical indicating whether to take the absolute value of the weights.                                      |
| scale         | logical indicating whether to scale all weights from -1 to 1 (or from 0 to 1 if abs=TRUE).                 |
| as.data.frame | logical indicating whether to return a long data frame instead of a list of matrices.<br>Default is FALSE. |

**Value**

By default it returns a list where each element is a loading matrix with dimensionality (D,K), where D is the number of features and K is the number of factors.

Alternatively, if `as.data.frame` is TRUE, returns a long-formatted data frame with columns (view,feature,factor,value).

**Examples**

```
# Using an existing trained model on simulated data
file <- system.file("extdata", "model.hdf5", package = "MOFA2")
model <- load_model(file)

# Fetch weights in matrix format (a list, one matrix per view)
weights <- get_weights(model)

# Fetch weights for factor 1 and 2 and view 1
weights <- get_weights(model, views = 1, factors = c(1,2))

# Fetch weights in data.frame format
weights <- get_weights(model, as.data.frame = TRUE)
```

---

groups\_names

*groups\_names: set and retrieve group names*


---

**Description**

groups\_names: set and retrieve group names

**Usage**

```
groups_names(object)

groups_names(object) <- value

## S4 method for signature 'MOFA'
groups_names(object)

## S4 replacement method for signature 'MOFA,character'
groups_names(object) <- value
```

**Arguments**

|        |  |
|--------|--|
| object | a <a href="#">MOFA</a> object.                 |
| value  | character vector with the names for each group |

**Value**

character vector with the names for each sample group

**Examples**

```
# Using an existing trained model on simulated data
file <- system.file("extdata", "model.hdf5", package = "MOFA2")
model <- load_model(file)
groups_names(model)
groups_names(model) <- c("my_group")
```

---

impute

*Impute missing values from a fitted MOFA*

---

**Description**

This function uses the latent factors and the loadings to impute missing values.

**Usage**

```
impute(
  object,
  views = "all",
  groups = "all",
  factors = "all",
  add_intercept = TRUE
)
```

**Arguments**

|               |   |
|---------------|---|
| object        | a <a href="#">MOFA</a> object.  |
| views         | character vector with the view name(s), or numeric vector with view index(es).  |
| groups        | character vector with the group name(s), or numeric vector with group index(es).  |
| factors       | character vector with the factor names, or numeric vector with the factor index(es). <ul style="list-style-type: none"> <li>• <b>response</b>: gives mean for gaussian and poisson and probabilities for bernoulli.</li> <li>• <b>link</b>: gives the linear predictions.</li> <li>• <b>inRange</b>: rounds the fitted values from "terms" for integer-valued distributions to the next integer (default).</li> </ul> |
| add_intercept | add feature intercepts to the imputation (default is TRUE).   |

**Details**

MOFA generates a denoised and condensed low-dimensional representation of the data that captures the main sources of heterogeneity of the data. This representation can be used to reconstruct the data, simply using the equation  $Y = WX$ . For more details read the supplementary methods of the manuscript.

Note that with [impute](#) you can only generate the point estimates (the means of the posterior distributions). If you want to add uncertainty estimates (the variance) you need to set `impute=TRUE` in the training options. See [get\\_default\\_training\\_options](#).

**Value**

This method fills the `imputed_data` slot by replacing the missing values in the input data with the model predictions.

**Examples**

```
# Using an existing trained model on simulated data
file <- system.file("extdata", "model.hdf5", package = "MOFA2")
model <- load_model(file)

# Impute missing values in all data modalities
imputed_data <- impute(model, views = "all")

# Impute missing values in all data modalities using factors 1:3
imputed_data <- impute(model, views = "all", factors = 1:3)
```

---

interpolate\_factors     *Interpolate factors in MEFISTO based on new covariate values*

---

**Description**

Function to interpolate factors in MEFISTO based on new covariate values.

**Usage**

```
interpolate_factors(object, new_values)
```

**Arguments**

**object** a MOFA object trained with MEFISTO options and a covariate  
**new\_values** a matrix containing the new covariate values to inter/extrapolate to. Should be in the same format as the covariates used for training.

**Details**

This function requires the functional MEFISTO framework to be used in training. Use `set_covariates` and specify `mefisto_options` when preparing the training using `prepare_mofa`. Currently, only the mean of the interpolation is provided from R.

**Value**

Returns the MOFA with interpolated factor values filled in the corresponding slot (`interpolatedZ`)

**Examples**

```
# Using an existing trained model
file <- system.file("extdata", "MEFISTO_model.hdf5", package = "MOFA2")
model <- load_model(file)
model <- interpolate_factors(model, new_values = seq(0,1.1,0.01))
```

---

load\_model

*Load a trained MOFA*


---

**Description**

Method to load a trained MOFA

The training of mofa is done using a Python framework, and the model output is saved as an .hdf5 file, which has to be loaded in the R package.

**Usage**

```
load_model(
  file,
  sort_factors = TRUE,
  on_disk = FALSE,
  load_data = TRUE,
  remove_outliers = FALSE,
  remove_inactive_factors = TRUE,
  verbose = FALSE,
  load_interpol_Z = FALSE
)
```



## Arguments

|                         |  |
|-------------------------|--|
| file                    | an hdf5 file saved by the mofa Python framework  |
| sort_factors            | logical indicating whether factors should be sorted by variance explained (default is TRUE)  |
| on_disk                 | logical indicating whether to work from memory (FALSE) or disk (TRUE). This should be set to TRUE when the training data is so big that cannot fit into memory. On-disk operations are performed using the <a href="#">HDF5Array</a> and <a href="#">DelayedArray</a> framework. |
| load_data               | logical indicating whether to load the training data (default is TRUE, it can be memory expensive)   |
| remove_outliers         | logical indicating whether to mask outlier values.   |
| remove_inactive_factors | logical indicating whether to remove inactive factors from the model.  |
| verbose                 | logical indicating whether to print verbose output (default is FALSE)  |
| load_interpol_Z         | (MEFISTO) logical indicating whether to load predictions for factor values based on latent processed (only relevant for models trained with covariates and Gaussian processes, where prediction was enabled)   |

## Value

a [MOFA](#) model

## Examples

```
#' # Using an existing trained model on simulated data
file <- system.file("extdata", "model.hdf5", package = "MOFA2")
model <- load_model(file)
```

---

make\_example\_data      *Simulate a data set using the generative model of MOFA*

---

## Description

Function to simulate an example multi-view multi-group data set according to the generative model of MOFA2.

**Usage**

```
make_example_data(  
  n_views = 3,  
  n_features = 100,  
  n_samples = 50,  
  n_groups = 1,  
  n_factors = 5,  
  likelihood = "gaussian",  
  lscales = 1,  
  sample_cov = NULL,  
  as.data.frame = FALSE  
)
```

**Arguments**

|               |  |
|---------------|--|
| n_views       | number of views  |
| n_features    | number of features in each view  |
| n_samples     | number of samples in each group  |
| n_groups      | number of groups   |
| n_factors     | number of factors  |
| likelihood    | likelihood for each view, one of "gaussian" (default), "bernoulli", "poisson", or a character vector of length n_views   |
| lscales       | vector of lengthscales, needs to be of length n_factors (default is 0 - no smooth factors)   |
| sample_cov    | (only for use with MEFISTO) matrix of sample covariates for one group with covariates in rows and samples in columns or "equidistant" for sequential ordering, default is NULL (no smooth factors) |
| as.data.frame | return data and covariates as long dataframe   |

**Value**

Returns a list containing the simulated data and simulation parameters.

**Examples**

```
# Generate a simulated data set  
MOFAexample <- make_example_data()
```

---

MOFA

*Class to store a mofa model*

---

### **Description**

The MOFA is an S4 class used to store all relevant data to analyse a MOFA model

### **Slots**

`data` The input data

`intercepts` Feature intercepts

`samples_metadata` Samples metadata

`features_metadata` Features metadata.

`imputed_data` The imputed data.

`expectations` expected values of the factors and the loadings.

`dim_red` non-linear dimensionality reduction manifolds.

`training_stats` model training statistics.

`data_options` Data processing options.

`training_options` Model training options.

`stochastic_options` Stochastic variational inference options.

`model_options` Model options.

`mefisto_options` Options for the use of MEFISTO

`dimensions` Dimensionalities of the model: M for the number of views, G for the number of groups, N for the number of samples (per group), C for the number of covariates per sample, D for the number of features (per view), K for the number of factors.

`on_disk` Logical indicating whether data is loaded from disk.

`cache` Cache.

`status` Auxiliary variable indicating whether the model has been trained.

`covariates` optional slot to store sample covariate for training in MEFISTO

`covariates_warped` optional slot to store warped sample covariate for training in MEFISTO

`interpolated_Z` optional slot to store interpolated factor values (used only with MEFISTO)

---

|                |   |
|----------------|---|
| plot_alignment | <i>Plot covariate alignment across groups</i> |
|----------------|---|

---

**Description**

Function to plot the alignment learnt by MEFISTO for the covariate values between different groups

**Usage**

```
plot_alignment(object)
```

**Arguments**

object            a [MOFA](#) object using MEFISTO with warping

**Details**

This function requires the functional MEFISTO framework to be used in training. Use `set_covariates` and specify `mefisto_options` when preparing the training using `prepare_mofa`.

**Value**

ggplot object showing the alignment

---

|                 |  |
|-----------------|--|
| plot_ascii_data | <i>Visualize the structure of the data in the terminal</i> |
|-----------------|--|

---

**Description**

A Fancy printing method

**Usage**

```
plot_ascii_data(object, nonzero = FALSE)
```

**Arguments**

object            a [MOFA](#) object  
nonzero           a logical value specifying whether to calculate the fraction of non-zero values (non-NA values by default)

**Details**

This function is helpful to get an overview of the structure of the data as a text output

**Value**

None

**Examples**

```
# Using an existing trained model
file <- system.file("extdata", "model.hdf5", package = "MOFA2")
model <- load_model(file)
plot_ascii_data(model)
```

---

|                   |  |
|-------------------|--|
| plot_data_heatmap | <i>Plot heatmap of relevant features</i> |
|-------------------|--|

---

**Description**

Function to plot a heatmap of the data for relevant features, typically the ones with high weights.

**Usage**

```
plot_data_heatmap(  
  object,  
  factor,  
  view = 1,  
  groups = "all",  
  features = 50,  
  annotation_features = NULL,  
  annotation_samples = NULL,  
  transpose = FALSE,  
  imputed = FALSE,  
  denoise = FALSE,  
  max.value = NULL,  
  min.value = NULL,  
  ...  
)
```

**Arguments**

|          |  |
|----------|--|
| object   | a <a href="#">MOFA</a> object.   |
| factor   | a string with the factor name, or an integer with the index of the factor.   |
| view     | a string with the view name, or an integer with the index of the view. Default is the first view.  |
| groups   | groups to plot. Default is "all".  |
| features | if an integer (default), the total number of features to plot based on the absolute value of the weights. If a character vector, a set of manually defined features. |

|                     |   |
|---------------------|---|
| annotation_features | annotation metadata for features (rows). Either a character vector specifying columns in the feature metadata, or a data.frame that will be passed to <a href="#">pheatmap</a> as annotation_col  |
| annotation_samples  | annotation metadata for samples (columns). Either a character vector specifying columns in the sample metadata, or a data.frame that will be passed to <a href="#">pheatmap</a> as annotation_row |
| transpose           | logical indicating whether to transpose the heatmap. Default corresponds to features as rows and samples as columns.  |
| imputed             | logical indicating whether to plot the imputed data instead of the original data. Default is FALSE.   |
| denoise             | logical indicating whether to plot a denoised version of the data reconstructed using the MOFA factors.   |
| max.value           | numeric indicating the maximum value to display in the heatmap (i.e. the matrix values will be capped at max.value ).   |
| min.value           | numeric indicating the minimum value to display in the heatmap (i.e. the matrix values will be capped at min.value ). See <a href="#">predict</a> . Default is FALSE.                             |
| ...                 | further arguments that can be passed to <a href="#">pheatmap</a>  |

## Details

One of the first steps for the annotation of a given factor is to visualise the corresponding weights, using for example [plot\\_weights](#) or [plot\\_top\\_weights](#).

However, one might also be interested in visualising the direct relationship between features and factors, rather than looking at "abstract" weights.

This function generates a heatmap for selected features, which should reveal the underlying pattern that is captured by the latent factor.

A similar function for doing scatterplots rather than heatmaps is [plot\\_data\\_scatter](#).

## Value

A [pheatmap](#) object

## Examples

```
# Using an existing trained model
file <- system.file("extdata", "model.hdf5", package = "MOFA2")
model <- load_model(file)
plot_data_heatmap(model, factor = 1, show_rownames = FALSE, show_colnames = FALSE)
```

---

plot\_data\_overview      *Overview of the input data*

---

## Description

Function to do a tile plot showing the missing value structure of the input data

## Usage

```
plot_data_overview(  
  object,  
  covariate = 1,  
  colors = NULL,  
  show_covariate = FALSE,  
  show_dimensions = TRUE  
)
```

## Arguments

|                 |   |
|-----------------|---|
| object          | a <a href="#">MOFA</a> object.  |
| covariate       | (only for MEFISTO) specifies sample covariate to order samples by in the plot. This should be a character or a numeric index giving the name or position of a column present in the covariates slot of the object. Default is the first sample covariate in covariates slot. NULL does not order by covariate |
| colors          | a vector specifying the colors per view (see example for details).  |
| show_covariate  | (only for MEFISTO) boolean specifying whether to include the covariate in the plot  |
| show_dimensions | logical indicating whether to plot the dimensions of the data (default is TRUE).  |

## Details

This function is helpful to get an overview of the structure of the data. It shows the model dimensionalities (number of samples, groups, views and features) and it indicates which measurements are missing.

## Value

A [ggplot](#) object

## Examples

```
# Using an existing trained model  
file <- system.file("extdata", "model.hdf5", package = "MOFA2")  
model <- load_model(file)  
plot_data_overview(model)
```

---

plot\_data\_scatter      *Scatterplots of feature values against latent factors*

---

## Description

Function to do a scatterplot of features against factor values.

## Usage

```
plot_data_scatter(
  object,
  factor = 1,
  view = 1,
  groups = "all",
  features = 10,
  sign = "all",
  color_by = "group",
  legend = TRUE,
  alpha = 1,
  shape_by = NULL,
  stroke = NULL,
  dot_size = 2.5,
  text_size = NULL,
  add_lm = TRUE,
  lm_per_group = TRUE,
  imputed = FALSE
)
```

## Arguments

|          |  |
|----------|--|
| object   | a <a href="#">MOFA</a> object.   |
| factor   | string with the factor name, or an integer with the index of the factor.   |
| view     | string with the view name, or an integer with the index of the view. Default is the first view.  |
| groups   | groups to plot. Default is "all".  |
| features | if an integer (default), the total number of features to plot. If a character vector, a set of manually-defined features.  |
| sign     | can be 'positive', 'negative' or 'all' (default) to show only positive, negative or all weights, respectively.   |
| color_by | specifies groups or values (either discrete or continuous) used to color the dots (samples). This can be either: <ul style="list-style-type: none"> <li>the string "group": dots are coloured with respect to their predefined groups.</li> <li>a character giving the name of a feature that is present in the input data</li> <li>a character giving the same of a column in the sample metadata slot</li> </ul> |



|              |  |
|--------------|--|
|              | <ul style="list-style-type: none"> <li>• a vector of the same length as the number of samples specifying the value for each sample.</li> <li>• a dataframe with two columns: "sample" and "color"</li> </ul>   |
| legend       | logical indicating whether to add a legend   |
| alpha        | numeric indicating dot transparency (default is 1).  |
| shape_by     | specifies groups or values (only discrete) used to shape the dots (samples). This can be either: <ul style="list-style-type: none"> <li>• the string "group": dots are shaped with respect to their predefined groups.</li> <li>• a character giving the name of a feature that is present in the input data</li> <li>• a character giving the name of a column in the sample metadata slot</li> <li>• a vector of the same length as the number of samples specifying the value for each sample.</li> <li>• a dataframe with two columns: "sample" and "shape"</li> </ul> |
| stroke       | numeric indicating the stroke size (the black border around the dots, default is NULL, inferred automatically).  |
| dot_size     | numeric indicating dot size (default is 5).  |
| text_size    | numeric indicating text size (default is 5).   |
| add_lm       | logical indicating whether to add a linear regression line for each plot   |
| lm_per_group | logical indicating whether to add a linear regression line separately for each group   |
| imputed      | logical indicating whether to include imputed measurements   |

## Details

One of the first steps for the annotation of factors is to visualise the weights using [plot\\_weights](#) or [plot\\_top\\_weights](#). However, one might also be interested in visualising the direct relationship between features and factors, rather than looking at "abstract" weights.

A similar function for doing heatmaps rather than scatterplots is [plot\\_data\\_heatmap](#).

## Value

A [ggplot](#) object

## Examples

```
# Using an existing trained model
file <- system.file("extdata", "model.hdf5", package = "MOFA2")
model <- load_model(file)
plot_data_scatter(model)
```

---

plot\_data\_vs\_cov      *Scatterplots of feature values against sample covariates*

---

## Description

Function to do a scatterplot of features against sample covariate values.

## Usage

```
plot_data_vs_cov(  
  object,  
  covariate = 1,  
  warped = TRUE,  
  factor = 1,  
  view = 1,  
  groups = "all",  
  features = 10,  
  sign = "all",  
  color_by = "group",  
  legend = TRUE,  
  alpha = 1,  
  shape_by = NULL,  
  stroke = NULL,  
  dot_size = 2.5,  
  text_size = NULL,  
  add_lm = FALSE,  
  lm_per_group = FALSE,  
  imputed = FALSE,  
  return_data = FALSE  
)
```

## Arguments

|           |  |
|-----------|--|
| object    | a <a href="#">MOFA</a> object using MEFISTO.   |
| covariate | string with the covariate name or a <code>samples_metadata</code> column, or an integer with the index of the covariate                              |
| warped    | logical indicating whether to show the aligned covariate (default: TRUE), only relevant if warping has been used to align multiple sample groups     |
| factor    | string with the factor name, or an integer with the index of the factor to take top features from  |
| view      | string with the view name, or an integer with the index of the view. Default is the first view.  |
| groups    | groups to plot. Default is "all".  |
| features  | if an integer (default), the total number of features to plot (given by highest weights). If a character vector, a set of manually-defined features. |

|              |  |
|--------------|--|
| sign         | can be 'positive', 'negative' or 'all' (default) to show only features with highest positive, negative or all weights, respectively.   |
| color_by     | specifies groups or values (either discrete or continuous) used to color the dots (samples). This can be either: <ul style="list-style-type: none"> <li>• the string "group": dots are coloured with respect to their predefined groups.</li> <li>• a character giving the name of a feature that is present in the input data</li> <li>• a character giving the same of a column in the sample metadata slot</li> <li>• a vector of the same length as the number of samples specifying the value for each sample.</li> <li>• a dataframe with two columns: "sample" and "color"</li> </ul> |
| legend       | logical indicating whether to add a legend   |
| alpha        | numeric indicating dot transparency (default is 1).  |
| shape_by     | specifies groups or values (only discrete) used to shape the dots (samples). This can be either: <ul style="list-style-type: none"> <li>• the string "group": dots are shaped with respect to their predefined groups.</li> <li>• a character giving the name of a feature that is present in the input data</li> <li>• a character giving the same of a column in the sample metadata slot</li> <li>• a vector of the same length as the number of samples specifying the value for each sample.</li> <li>• a dataframe with two columns: "sample" and "shape"</li> </ul>                   |
| stroke       | numeric indicating the stroke size (the black border around the dots, default is NULL, inferred automatically).  |
| dot_size     | numeric indicating dot size (default is 5).  |
| text_size    | numeric indicating text size (default is 5).   |
| add_lm       | logical indicating whether to add a linear regression line for each plot   |
| lm_per_group | logical indicating whether to add a linear regression line separately for each group   |
| imputed      | logical indicating whether to include imputed measurements   |
| return_data  | logical indicating whether to return a data frame instead of a plot  |

## Details

One of the first steps for the annotation of factors is to visualise the weights using [plot\\_weights](#) or [plot\\_top\\_weights](#) and inspect the relationship of the factor to the covariate(s) using [plot\\_factors\\_vs\\_cov](#). However, one might also be interested in visualising the direct relationship between features and covariate(s), rather than looking at "abstract" weights and possibly look at the interpolated and extrapolated values by setting `imputed` to `True`.

## Value

Returns a `ggplot2` object or the underlying dataframe if `return_data` is set to `TRUE`.

## Examples

```
# Using an existing trained model
file <- system.file("extdata", "MEFISTO_model.hdf5", package = "MOFA2")
model <- load_model(file)
plot_data_vs_cov(model, factor = 3, features = 2)
```

---

plot\_dimred

*Plot dimensionality reduction based on MOFA factors*

---

## Description

Plot dimensionality reduction based on MOFA factors

## Usage

```
plot_dimred(
  object,
  method = c("UMAP", "TSNE"),
  groups = "all",
  show_missing = TRUE,
  color_by = NULL,
  shape_by = NULL,
  color_name = NULL,
  shape_name = NULL,
  label = FALSE,
  dot_size = 1.5,
  stroke = NULL,
  alpha_missing = 1,
  legend = TRUE,
  rasterize = FALSE,
  return_data = FALSE,
  ...
)
```

## Arguments

|              |  |
|--------------|--|
| object       | a trained <a href="#">MOFA</a> object.   |
| method       | string indicating which method has been used for non-linear dimensionality reduction (either 'umap' or 'tsne')                                       |
| groups       | character vector with the groups names, or numeric vector with the indices of the groups of samples to use, or "all" to use samples from all groups. |
| show_missing | logical indicating whether to include samples for which shape_by or color_by is missing  |

|               |  |
|---------------|--|
| color_by      | specifies groups or values used to color the samples. This can be either: (1) a character giving the name of a feature present in the training data. (2) a character giving the name of a column present in the sample metadata. (3) a vector of the same length as the number of samples specifying discrete groups or continuous numeric values. |
| shape_by      | specifies groups or values used to shape the samples. This can be either: (1) a character giving the name of a feature present in the training data, (2) a character giving the name of a column present in the sample metadata. (3) a vector of the same length as the number of samples specifying discrete groups.                              |
| color_name    | name for color legend.   |
| shape_name    | name for shape legend.   |
| label         | logical indicating whether to label the medians of the clusters. Only if color_by is specified   |
| dot_size      | numeric indicating dot size.   |
| stroke        | numeric indicating the stroke size (the black border around the dots, default is NULL, inferred automatically).  |
| alpha_missing | numeric indicating dot transparency of missing data.   |
| legend        | logical indicating whether to add legend.  |
| rasterize     | logical indicating whether to rasterize plot using <code>geom_point_rast</code>  |
| return_data   | logical indicating whether to return the long data frame to plot instead of plotting   |
| ...           | extra arguments passed to <code>run_umap</code> or <code>run_tsne</code> .   |

### Details

This function plots dimensionality reduction projections that are stored in the `dim_red` slot. Typically this contains UMAP or t-SNE projections computed using `run_tsne` or `run_umap`, respectively.

### Value

Returns a `ggplot2` object or a long data.frame (if `return_data` is TRUE)

### Examples

```
# Using an existing trained model on simulated data
file <- system.file("extdata", "model.hdf5", package = "MOFA2")
model <- load_model(file)

# Run UMAP
model <- run_umap(model)

# Plot UMAP
plot_dimred(model, method = "UMAP")

# Plot UMAP, colour by Factor 1 values
plot_dimred(model, method = "UMAP", color_by = "Factor1")
```

```
# Plot UMAP, colour by the values of a specific feature
plot_dimred(model, method = "UMAP", color_by = "feature_0_view_0")
```

---

plot\_enrichment      *Plot output of gene set Enrichment Analysis*

---

## Description

Method to plot the results of the gene set Enrichment Analysis

## Usage

```
plot_enrichment(
  enrichment.results,
  factor,
  alpha = 0.1,
  max.pathways = 25,
  text_size = 1,
  dot_size = 5
)
```

## Arguments

|                    |   |
|--------------------|---|
| enrichment.results | output of <a href="#">run_enrichment</a> function                 |
| factor             | a string with the factor name or an integer with the factor index |
| alpha              | p.value threshold to filter out gene sets                         |
| max.pathways       | maximum number of enriched pathways to display                    |
| text_size          | text size   |
| dot_size           | dot size  |

## Details

it requires [run\\_enrichment](#) to be run beforehand.

## Value

a ggplot2 object

---

`plot_enrichment_detailed`*Plot detailed output of the Feature Set Enrichment Analysis*

---

## Description

Method to plot a detailed output of the Feature Set Enrichment Analysis (FSEA).

Each row corresponds to a significant pathway, sorted by statistical significance, and each dot corresponds to a gene.

For each pathway, we display the top genes of the pathway sorted by the corresponding feature statistic (by default, the absolute value of the weight) The top genes with the highest statistic (`max.genes` argument) are displayed and labeled in black. The remaining genes are colored in grey.

## Usage

```
plot_enrichment_detailed(  
  enrichment.results,  
  factor,  
  alpha = 0.1,  
  max.genes = 5,  
  max.pathways = 10,  
  text_size = 3  
)
```

## Arguments

|                                 |  |
|---------------------------------|--|
| <code>enrichment.results</code> | output of <a href="#">run_enrichment</a> function    |
| <code>factor</code>             | string with factor name or numeric with factor index |
| <code>alpha</code>              | p.value threshold to filter out feature sets         |
| <code>max.genes</code>          | maximum number of genes to display, per pathway      |
| <code>max.pathways</code>       | maximum number of enriched pathways to display       |
| <code>text_size</code>          | size of the text to label the top genes              |

## Value

a `ggplot2` object

---

plot\_enrichment\_heatmap

*Heatmap of Feature Set Enrichment Analysis results*

---

### Description

This method generates a heatmap with the adjusted p-values that result from the the feature set enrichment analysis. Rows are feature sets and columns are factors.

### Usage

```
plot_enrichment_heatmap(
  enrichment.results,
  alpha = 0.1,
  cap = 1e-50,
  log_scale = TRUE,
  ...
)
```

### Arguments

|                    |   |
|--------------------|---|
| enrichment.results | output of <a href="#">run_enrichment</a> function   |
| alpha              | FDR threshold to filter out insignificant feature sets which are not represented in the heatmap. Default is 0.10. |
| cap                | cap p-values below this threshold   |
| log_scale          | logical indicating whether to plot the -log of the p.values.  |
| ...                | extra arguments to be passed to the <a href="#">pheatmap</a> function   |

### Value

produces a heatmap

---

plot\_factor

*Beeswarm plot of factor values*

---

### Description

Beeswarm plot of the latent factor values.



**Usage**

```

plot_factor(
  object,
  factors = 1,
  groups = "all",
  group_by = "group",
  color_by = "group",
  shape_by = NULL,
  add_dots = TRUE,
  dot_size = 2,
  dot_alpha = 1,
  add_violin = FALSE,
  violin_alpha = 0.5,
  color_violin = TRUE,
  add_boxplot = FALSE,
  boxplot_alpha = 0.5,
  color_boxplot = TRUE,
  show_missing = TRUE,
  scale = FALSE,
  dodge = FALSE,
  color_name = "",
  shape_name = "",
  stroke = NULL,
  legend = TRUE,
  rasterize = FALSE
)

```

**Arguments**

|          |  |
|----------|--|
| object   | a trained <a href="#">MOFA</a> object.   |
| factors  | character vector with the factor names, or numeric vector with the indices of the factors to use, or "all" to plot all factors.  |
| groups   | character vector with the groups names, or numeric vector with the indices of the groups of samples to use, or "all" to use samples from all groups.   |
| group_by | specifies grouping of samples: <ul style="list-style-type: none"> <li>• (default) the string "group": in this case, the plot will color samples with respect to their predefined groups.</li> <li>• a character giving the name of a feature that is present in the input data</li> <li>• a character giving the name of a column in the sample metadata slot</li> <li>• a vector of the same length as the number of samples specifying the value for each sample.</li> </ul> |
| color_by | specifies color of samples. This can be either: <ul style="list-style-type: none"> <li>• (default) the string "group": in this case, the plot will color the dots with respect to their predefined groups.</li> <li>• a character giving the name of a feature that is present in the input data</li> <li>• a character giving the name of a column in the sample metadata slot</li> </ul>   |

|               |   |
|---------------|---|
|               | <ul style="list-style-type: none"> <li>• a vector of the same length as the number of samples specifying the value for each sample.</li> </ul>  |
| shape_by      | <p>specifies shape of samples. This can be either:</p> <ul style="list-style-type: none"> <li>• (default) the string "group": in this case, the plot will shape the dots with respect to their predefined groups.</li> <li>• a character giving the name of a feature that is present in the input data</li> <li>• a character giving the name of a column in the sample metadata slot</li> <li>• a vector of the same length as the number of samples specifying the value for each sample.</li> </ul> |
| add_dots      | logical indicating whether to add dots.   |
| dot_size      | numeric indicating dot size.  |
| dot_alpha     | numeric indicating dot transparency.  |
| add_violin    | logical indicating whether to add violin plots  |
| violin_alpha  | numeric indicating violin plot transparency.  |
| color_violin  | logical indicating whether to color violin plots.   |
| add_boxplot   | logical indicating whether to add box plots   |
| boxplot_alpha | numeric indicating boxplot transparency.  |
| color_boxplot | logical indicating whether to color box plots.  |
| show_missing  | logical indicating whether to remove samples for which shape_by or color_by is missing.   |
| scale         | logical indicating whether to scale factor values.  |
| dodge         | logical indicating whether to dodge the dots (default is FALSE).  |
| color_name    | name for color legend (usually only used if color_by is not a character itself).  |
| shape_name    | name for shape legend (usually only used if shape_by is not a character itself).  |
| stroke        | numeric indicating the stroke size (the black border around the dots).  |
| legend        | logical indicating whether to add a legend to the plot (default is TRUE).   |
| rasterize     | logical indicating whether to rasterize the plot (default is FALSE).  |

## Details

One of the main steps for the annotation of factors is to visualise and color them using known covariates or phenotypic data.

This function generates a Beeswarm plot of the sample values in a given latent factor.

Similar functions are [plot\\_factors](#) for doing scatter plots.

## Value

Returns a ggplot2

### Examples

```
# Using an existing trained model on simulated data
file <- system.file("extdata", "model.hdf5", package = "MOFA2")
model <- load_model(file)

# Plot Factors 1 and 2 and colour by "group"
plot_factor(model, factors = c(1,2), color_by="group")

# Plot Factor 3 and colour by the value of a specific feature
plot_factor(model, factors = 3, color_by="feature_981_view_1")

# Add violin plots
plot_factor(model, factors = c(1,2), color_by="group", add_violin = TRUE)

# Scale factor values from -1 to 1
plot_factor(model, factors = c(1,2), scale = TRUE)
```

---

plot\_factors

*Scatterplots of two factor values*

---

### Description

Scatterplot of the values of two latent factors.

### Usage

```
plot_factors(
  object,
  factors = c(1, 2),
  groups = "all",
  show_missing = TRUE,
  scale = FALSE,
  color_by = NULL,
  shape_by = NULL,
  color_name = NULL,
  shape_name = NULL,
  dot_size = 2,
  alpha = 1,
  legend = TRUE,
  stroke = NULL,
  return_data = FALSE
)
```

### Arguments

object            a trained [MOFA](#) object.

|              |  |
|--------------|--|
| factors      | a vector of length two with the factors to plot. Factors can be specified either as a characters   |
| groups       | character vector with the groups names, or numeric vector with the indices of the groups of samples to use, or "all" to use samples from all groups.   |
| show_missing | logical indicating whether to include samples for which shape_by or color_by is missing  |
| scale        | logical indicating whether to scale factor values.   |
| color_by     | specifies groups or values used to color the samples. This can be either: (1) a character giving the name of a feature present in the training data. (2) a character giving the name of a column present in the sample metadata. (3) a vector of the name length as the number of samples specifying discrete groups or continuous numeric values. |
| shape_by     | specifies groups or values used to shape the samples. This can be either: (1) a character giving the name of a feature present in the training data, (2) a character giving the name of a column present in the sample metadata. (3) a vector of the same length as the number of samples specifying discrete groups.                              |
| color_name   | name for color legend.   |
| shape_name   | name for shape legend.   |
| dot_size     | numeric indicating dot size (default is 2).  |
| alpha        | numeric indicating dot transparency (default is 1).  |
| legend       | logical indicating whether to add legend.  |
| stroke       | numeric indicating the stroke size (the black border around the dots, default is NULL, inferred automatically).  |
| return_data  | logical indicating whether to return the data frame to plot instead of plotting  |

## Details

One of the first steps for the annotation of factors is to visualise and group/color them using known covariates such as phenotypic or clinical data. This method generates a single scatterplot for the combination of two latent factors. TO-FINISH... [plot\\_factors](#) for doing Beeswarm plots for factors.

## Value

Returns a ggplot2 object

## Examples

```
# Using an existing trained model on simulated data
file <- system.file("extdata", "model.hdf5", package = "MOFA2")
model <- load_model(file)

# Scatterplot of factors 1 and 2
plot_factors(model, factors = c(1,2))

# Shape dots by a column in the metadata
```

```

plot_factors(model, factors = c(1,2), shape_by="group")

# Scale factor values from -1 to 1
plot_factors(model, factors = c(1,2), scale = TRUE)

```

---

plot\_factors\_vs\_cov     *Scatterplots of a factor's values against the sample covariates*

---

## Description

Scatterplots of a factor's values against the sample covariates

## Usage

```

plot_factors_vs_cov(
  object,
  factors = "all",
  covariates = NULL,
  warped = TRUE,
  show_missing = TRUE,
  scale = FALSE,
  color_by = NULL,
  shape_by = NULL,
  color_name = NULL,
  shape_name = NULL,
  dot_size = 1.5,
  alpha = 1,
  stroke = NULL,
  legend = TRUE,
  rotate_x = FALSE,
  rotate_y = FALSE,
  return_data = FALSE,
  show_variance = FALSE
)

```

## Arguments

|            |  |
|------------|--|
| object     | a trained <a href="#">MOFA</a> object using MEFISTO.   |
| factors    | character or numeric specifying the factor(s) to plot, default is "all"  |
| covariates | specifies sample covariate(s) to plot against: (1) a character giving the name of a column present in the sample covariates or sample metadata. (2) a character giving the name of a feature present in the training data. (3) a vector of the same length as the number of samples specifying continuous numeric values per sample. Default is the first sample covariates in covariates slot |
| warped     | logical indicating whether to show the aligned covariate (default: TRUE), only relevant if warping has been used to align multiple sample groups   |

|               |   |
|---------------|---|
| show_missing  | (for 1-dim covariates) logical indicating whether to include samples for which shape_by or color_by is missing  |
| scale         | logical indicating whether to scale factor values.  |
| color_by      | (for 1-dim covariates) specifies groups or values used to color the samples. This can be either: (1) a character giving the name of a feature present in the training data. (2) a character giving the name of a column present in the sample metadata. (3) a vector of the same length as the number of samples specifying discrete groups or continuous numeric values. |
| shape_by      | (for 1-dim covariates) specifies groups or values used to shape the samples. This can be either: (1) a character giving the name of a feature present in the training data, (2) a character giving the name of a column present in the sample metadata. (3) a vector of the same length as the number of samples specifying discrete groups.                              |
| color_name    | (for 1-dim covariates) name for color legend.   |
| shape_name    | (for 1-dim covariates) name for shape legend.   |
| dot_size      | (for 1-dim covariates) numeric indicating dot size.   |
| alpha         | (for 1-dim covariates) numeric indicating dot transparency.   |
| stroke        | (for 1-dim covariates) numeric indicating the stroke size   |
| legend        | (for 1-dim covariates) logical indicating whether to add legend.  |
| rotate_x      | (for spatial, 2-dim covariates) Rotate covariate on x-axis  |
| rotate_y      | (for spatial, 2-dim covariates) Rotate covariate on y-axis  |
| return_data   | logical indicating whether to return the data frame to plot instead of plotting   |
| show_variance | (for 1-dim covariates) logical indicating whether to show the marginal variance of inferred factor values (only relevant for 1-dimensional covariates)  |

## Details

To investigate the factors pattern along the covariates (such as time or a spatial coordinate) this function can be used to plot a scatterplot of the factor against the values of each covariate

## Value

Returns a ggplot2 object

## Examples

```
# Using an existing trained model
file <- system.file("extdata", "MEFISTO_model.hdf5", package = "MOFA2")
model <- load_model(file)
plot_factors_vs_cov(model)
```

---

|                 |   |
|-----------------|---|
| plot_factor_cor | <i>Plot correlation matrix between latent factors</i> |
|-----------------|---|

---

### Description

Function to plot the correlation matrix between the latent factors.

### Usage

```
plot_factor_cor(object, method = "pearson", ...)
```

### Arguments

|        |   |
|--------|---|
| object | a trained <a href="#">MOFA</a> object.  |
| method | a character indicating the type of correlation coefficient to be computed: pearson (default), kendall, or spearman. |
| ...    | arguments passed to <a href="#">corrplot</a>  |

### Details

This method plots the correlation matrix between the latent factors.

The model encourages the factors to be uncorrelated, so this function usually yields a diagonal correlation matrix.

However, it is not a hard constraint such as in Principal Component Analysis and correlations between factors can occur, particularly with large number factors.

Generally, correlated factors are redundant and should be avoided, as they make interpretation harder. Therefore, if you have too many correlated factors we suggest you try reducing the number of factors.

### Value

Returns a symmetric matrix with the correlation coefficient between every pair of factors.

### Examples

```
# Using an existing trained model on simulated data
file <- system.file("extdata", "model.hdf5", package = "MOFA2")
model <- load_model(file)

# Plot correlation between all factors
plot_factor_cor(model)
```

---

|                   |   |
|-------------------|---|
| plot_group_kernel | <i>Heatmap plot showing the group-group correlations per factor</i> |
|-------------------|---|

---

### Description

Heatmap plot showing the group-group correlations inferred by the model per factor

### Usage

```
plot_group_kernel(object, factors = "all", groups = "all", ...)
```

### Arguments

|         |  |
|---------|--|
| object  | a trained <a href="#">MOFA</a> object using MEFISTO.   |
| factors | character vector with the factors names, or numeric vector indicating the indices of the factors to use  |
| groups  | character vector with the groups names, or numeric vector with the indices of the groups of samples to use, or "all" to use samples from all groups. |
| ...     | additional parameters that can be passed to pheatmap   |

### Details

The heatmap gives insight into the clustering of the patterns that factors display along the covariate in each group. A correlation of 1 indicates that the module captured by a factor shows identical patterns across groups, a correlation of zero that it shows distinct patterns, a negative correlation that the patterns go in opposite directions.

### Value

Returns a `ggplot,gg` object containing the heatmaps

### Examples

```
# Using an existing trained model on simulated data
file <- system.file("extdata", "MEFISTO_model.hdf5", package = "MOFA2")
model <- load_model(file)
plot_group_kernel(model)
```



---

`plot_interpolation_vs_covariate`*Plot interpolated factors versus covariate (1-dimensional)*

---

**Description**

make a plot of interpolated covariates versus covariate

**Usage**

```
plot_interpolation_vs_covariate(  
  object,  
  covariate = 1,  
  factors = "all",  
  only_mean = TRUE,  
  show_observed = TRUE  
)
```

**Arguments**

|                            |   |
|----------------------------|---|
| <code>object</code>        | a trained <a href="#">MOFA</a> object using MEFISTO.                    |
| <code>covariate</code>     | covariate to use for plotting   |
| <code>factors</code>       | character or numeric specifying the factor(s) to plot, default is "all" |
| <code>only_mean</code>     | show only mean or include uncertainties?                                |
| <code>show_observed</code> | include observed factor values as dots on the plot                      |

**Details**

to be filled

**Value**

Returns a ggplot2 object

**Examples**

```
# Using an existing trained model  
file <- system.file("extdata", "MEFISTO_model.hdf5", package = "MOFA2")  
model <- load_model(file)  
model <- interpolate_factors(model, new_values = seq(0,1.1,0.1))  
plot_interpolation_vs_covariate(model, covariate = "time", factors = 1)
```

---

plot\_sharedness      *Barplot showing the sharedness per factor*

---

### Description

Barplot indicating a sharedness score (between 0 (non-shared) and 1 (shared)) per factor

### Usage

```
plot_sharedness(object, factors = "all", color = "#B8CF87")
```

### Arguments

|         |   |
|---------|---|
| object  | a trained <a href="#">MOFA</a> object using MEFISTO.  |
| factors | character vector with the factors names, or numeric vector indicating the indices of the factors to use |
| color   | for the shared part of the bar  |

### Details

The sharedness score is calculated as the distance of the learnt group correlation matrix to the identity matrix in terms of the mean absolute distance on the off-diagonal elements.

### Value

Returns a ggplot2 object

---

plot\_smoothness      *Barplot showing the smoothness per factor*

---

### Description

Barplot indicating a smoothness score (between 0 (non-smooth) and 1 (smooth)) per factor

### Usage

```
plot_smoothness(object, factors = "all", color = "cadetblue")
```

### Arguments

|         |   |
|---------|---|
| object  | a trained <a href="#">MOFA</a> object using MEFISTO.  |
| factors | character vector with the factors names, or numeric vector indicating the indices of the factors to use |
| color   | for the smooth part of the bar  |

## Details

The smoothness score is given by the scale parameter for the underlying Gaussian process of each factor.

## Value

Returns a ggplot2 object

## Examples

```
# Using an existing trained model
file <- system.file("extdata", "MEFISTO_model.hdf5", package = "MOFA2")
model <- load_model(file)
smoothness_bars <- plot_smoothness(model)
```

---

plot\_top\_weights      *Plot top weights*

---

## Description

Plot top weights for a given factor and view.

## Usage

```
plot_top_weights(
  object,
  view = 1,
  factors = 1,
  nfeatures = 10,
  abs = TRUE,
  scale = TRUE,
  sign = "all"
)
```

## Arguments

|           |  |
|-----------|--|
| object    | a trained <a href="#">MOFA</a> object.   |
| view      | a string with the view name, or an integer with the index of the view.   |
| factors   | a character string with factors names, or an integer vector with factors indices.                                      |
| nfeatures | number of top features to display. Default is 10   |
| abs       | logical indicating whether to use the absolute value of the weights (Default is FALSE).                                |
| scale     | logical indicating whether to scale all weights from -1 to 1 (or from 0 to 1 if abs=TRUE). Default is TRUE.            |
| sign      | can be 'positive', 'negative' or 'all' to show only positive, negative or all weights, respectively. Default is 'all'. |

## Details

An important step to annotate factors is to visualise the corresponding feature weights.

This function displays the top features with highest loading whereas the function `plot_top_weights` plots all weights for a given latent factor and view.

Importantly, the weights of the features within a view have relative values and they should not be interpreted in an absolute scale. Therefore, for interpretability purposes we always recommend to scale the weights with `scale=TRUE`.

## Value

Returns a ggplot2 object

## Examples

```
# Using an existing trained model on simulated data
file <- system.file("extdata", "model.hdf5", package = "MOFA2")
model <- load_model(file)

# Plot top weights for Factors 1 and 2 and View 1
plot_top_weights(model, view = 1, factors = c(1,2))

# Do not take absolute value
plot_weights(model, abs = FALSE)
```

---

plot\_variance\_explained

*Plot variance explained by the model*

---

## Description

plots the variance explained by the MOFA factors across different views and groups, as specified by the user. Consider using `cowplot::plot_grid(plotlist = ...)` to combine the multiple plots that this function generates.

## Usage

```
plot_variance_explained(
  object,
  x = "view",
  y = "factor",
  split_by = NA,
  plot_total = FALSE,
  factors = "all",
  min_r2 = 0,
  max_r2 = NULL,
  legend = TRUE,
  use_cache = TRUE,
```

```
    ...
  )
```

### Arguments

|            |  |
|------------|--|
| object     | a <a href="#">MOFA</a> object  |
| x          | character specifying the dimension for the x-axis ("view", "factor", or "group").                                |
| y          | character specifying the dimension for the y-axis ("view", "factor", or "group").                                |
| split_by   | character specifying the dimension to be faceted ("view", "factor", or "group").                                 |
| plot_total | logical value to indicate if to plot the total variance explained (for the variable in the x-axis)               |
| factors    | character vector with a factor name(s), or numeric vector with the index(es) of the factor(s). Default is "all". |
| min_r2     | minimum variance explained for the color scheme (default is 0).  |
| max_r2     | maximum variance explained for the color scheme.   |
| legend     | logical indicating whether to add a legend to the plot (default is TRUE).  |
| use_cache  | logical indicating whether to use cache (default is TRUE)  |
| ...        | extra arguments to be passed to <a href="#">calculate_variance_explained</a>                                     |

### Value

A list of [ggplot](#) objects (if `plot_total` is TRUE) or a single [ggplot](#) object

### Examples

```
# Using an existing trained model on simulated data
file <- system.file("extdata", "model.hdf5", package = "MOFA2")
model <- load_model(file)

# Calculate variance explained (R2)
r2 <- calculate_variance_explained(model)

# Plot variance explained values (view as x-axis, and factor as y-axis)
plot_variance_explained(model, x="view", y="factor")

# Plot variance explained values (view as x-axis, and group as y-axis)
plot_variance_explained(model, x="view", y="group")

# Plot variance explained values for factors 1 to 3
plot_variance_explained(model, x="view", y="group", factors=1:3)

# Scale R2 values
plot_variance_explained(model, max_r2=0.25)
```

---

```
plot_variance_explained_by_covariates
```

*Plot variance explained by the smooth components of the model*

---

### Description

This function plots the variance explained by the smooth components (Gaussian processes) underlying the factors in MEFISTO across different views and groups, as specified by the user.

### Usage

```
plot_variance_explained_by_covariates(
  object,
  factors = "all",
  x = "view",
  y = "factor",
  split_by = NA,
  min_r2 = 0,
  max_r2 = NULL,
  compare_total = FALSE,
  legend = TRUE
)
```

### Arguments

|                            |  |
|----------------------------|--|
| <code>object</code>        | a <a href="#">MOFA</a> object  |
| <code>factors</code>       | character vector with a factor name(s), or numeric vector with the index(es) of the factor(s). Default is "all". |
| <code>x</code>             | character specifying the dimension for the x-axis ("view", "factor", or "group").                                |
| <code>y</code>             | character specifying the dimension for the y-axis ("view", "factor", or "group").                                |
| <code>split_by</code>      | character specifying the dimension to be faceted ("view", "factor", or "group").                                 |
| <code>min_r2</code>        | minimum variance explained for the color scheme (default is 0).  |
| <code>max_r2</code>        | maximum variance explained for the color scheme.   |
| <code>compare_total</code> | plot corresponding variance explained in total in addition   |
| <code>legend</code>        | logical indicating whether to add a legend to the plot (default is TRUE).  |

### Details

Note that this function requires the use of MEFISTO. To activate the functional MEFISTO framework, specify `mefisto_options` when preparing the training using `prepare_mofa`

### Value

A list of [ggplot](#) objects (if `compare_total` is TRUE) or a single [ggplot](#) object. Consider using `cowplot::plot_grid(plotlist = ...)` to combine the multiple plots that this function generates.

**Examples**

```
# load_model
file <- system.file("extdata", "MEFISTO_model.hdf5", package = "MOFA2")
model <- load_model(file)
plot_variance_explained_by_covariates(model)

# compare to total variance explained
plist <- plot_variance_explained_by_covariates(model, compare_total = TRUE)
cowplot::plot_grid(plotlist = plist)
```

---

plot\_variance\_explained\_per\_feature

*Plot variance explained by the model for a set of features Returns a tile plot with a group on the X axis and a feature along the Y axis*

---

**Description**

Plot variance explained by the model for a set of features

Returns a tile plot with a group on the X axis and a feature along the Y axis

**Usage**

```
plot_variance_explained_per_feature(
  object,
  view,
  features = 10,
  split_by_factor = FALSE,
  group_features_by = NULL,
  groups = "all",
  factors = "all",
  min_r2 = 0,
  max_r2 = NULL,
  legend = TRUE,
  return_data = FALSE,
  ...
)
```

**Arguments**

|                 |   |
|-----------------|---|
| object          | a <a href="#">MOFA</a> object.  |
| view            | a view name or index.   |
| features        | a vector with indices or names for features from the respective view, or number of top features to be fetched by their loadings across specified factors. "all" to plot all features. |
| split_by_factor | logical indicating whether to split R2 per factor or plot R2 jointly  |

|                   |   |
|-------------------|---|
| group_features_by | column name of features metadata to group features by                           |
| groups            | a vector with indices or names for sample groups (default is all)               |
| factors           | a vector with indices or names for factors (default is all)                     |
| min_r2            | minimum variance explained for the color scheme (default is 0).                 |
| max_r2            | maximum variance explained for the color scheme.                                |
| legend            | logical indicating whether to add a legend to the plot (default is TRUE).       |
| return_data       | logical indicating whether to return the data frame to plot instead of plotting |
| ...               | extra arguments to be passed to <a href="#">calculate_variance_explained</a>    |

**Value**

ggplot object

**Examples**

```
# Using an existing trained model
file <- system.file("extdata", "model.hdf5", package = "MOFA2")
model <- load_model(file)
plot_variance_explained_per_feature(model, view = 1)
```

---

plot\_weights

*Plot distribution of feature weights (weights)*

---

**Description**

An important step to annotate factors is to visualise the corresponding feature weights. This function plots all weights for a given latent factor and view, labeling the top ones. In contrast, the function [plot\\_top\\_weights](#) displays only the top features with highest loading.

**Usage**

```
plot_weights(
  object,
  view = 1,
  factors = 1,
  nfeatures = 10,
  color_by = NULL,
  shape_by = NULL,
  abs = FALSE,
  manual = NULL,
  color_manual = NULL,
  scale = TRUE,
  dot_size = 1,
  text_size = 5,
  legend = TRUE,
  return_data = FALSE
)
```



**Arguments**

|              |  |
|--------------|--|
| object       | a <a href="#">MOFA</a> object.   |
| view         | a string with the view name, or an integer with the index of the view.   |
| factors      | character vector with the factor name(s), or numeric vector with the index of the factor(s).   |
| nfeatures    | number of top features to label.   |
| color_by     | specifies groups or values (either discrete or continuous) used to color the dots (features). This can be either: <ul style="list-style-type: none"><li>• (default) the string "group": in this case, the plot will color the dots with respect to their predefined groups.</li><li>• a character giving the name of a feature that is present in the input data</li><li>• a character giving the same of a column in the features metadata slot</li><li>• a vector of the same length as the number of features specifying the value for each feature</li><li>• a dataframe with two columns: "feature" and "color"</li></ul> |
| shape_by     | specifies groups or values (only discrete) used to shape the dots (features). This can be either: <ul style="list-style-type: none"><li>• (default) the string "group": in this case, the plot will shape the dots with respect to their predefined groups.</li><li>• a character giving the name of a feature that is present in the input data</li><li>• a character giving the same of a column in the features metadata slot</li><li>• a vector of the same length as the number of features specifying the value for each feature</li><li>• a dataframe with two columns: "feature" and "shape"</li></ul>                 |
| abs          | logical indicating whether to take the absolute value of the weights.  |
| manual       | A nested list of character vectors with features to be manually labelled (see the example for details).  |
| color_manual | a character vector with colors, one for each element of 'manual'   |
| scale        | logical indicating whether to scale all weights from -1 to 1 (or from 0 to 1 if abs=TRUE).   |
| dot_size     | numeric indicating the dot size.   |
| text_size    | numeric indicating the text size.  |
| legend       | logical indicating whether to add legend.  |
| return_data  | logical indicating whether to return the data frame to plot instead of plotting  |

**Value**

A [ggplot](#) object or a `data.frame` if `return_data` is TRUE

## Examples

```
# Using an existing trained model on simulated data
file <- system.file("extdata", "model.hdf5", package = "MOFA2")
model <- load_model(file)

# Plot distribution of weights for Factor 1 and View 1
plot_weights(model, view = 1, factors = 1)

# Plot distribution of weights for Factors 1 to 3 and View 1
plot_weights(model, view = 1, factors = 1:3)

# Take the absolute value and highlight the top 10 features
plot_weights(model, view = 1, factors = 1, nfeatures = 10, abs = TRUE)

# Change size of dots and text
plot_weights(model, view = 1, factors = 1, text_size = 5, dot_size = 1)
```

---

plot\_weights\_heatmap *Plot heatmap of the weights*

---

## Description

Function to visualize the weights for a given set of factors in a given view.

This is useful to visualize the overall pattern of the weights but not to individually characterise the factors.

To inspect the weights of individual factors, use the functions [plot\\_weights](#) and [plot\\_top\\_weights](#)

## Usage

```
plot_weights_heatmap(
  object,
  view = 1,
  features = "all",
  factors = "all",
  threshold = 0,
  ...
)
```

## Arguments

|          |  |
|----------|--|
| object   | a trained <a href="#">MOFA</a> object.   |
| view     | character vector with the view name(s), or numeric vector with the index of the view(s) to use. Default is the first view. |
| features | character vector with the feature name(s), or numeric vector with the index of the feature(s) to use. Default is 'all'.    |

|           |   |
|-----------|---|
| factors   | character vector with the factor name(s), or numeric vector with the index of the factor(s) to use. Default is 'all'.   |
| threshold | threshold on absolute weight values, so that weights with a magnitude below this threshold (in all factors) are removed |
| ...       | extra arguments passed to <a href="#">pheatmap</a> .  |

**Value**

A [pheatmap](#) object

**Examples**

```
# Using an existing trained model on simulated data
file <- system.file("extdata", "model.hdf5", package = "MOFA2")
model <- load_model(file)
plot_weights_heatmap(model)
```

---

plot\_weights\_scatter *Scatterplots of weights*

---

**Description**

Scatterplot of the weights values for two factors

**Usage**

```
plot_weights_scatter(
  object,
  factors,
  view = 1,
  color_by = NULL,
  shape_by = NULL,
  dot_size = 1,
  name_color = "",
  name_shape = "",
  show_missing = TRUE,
  abs = FALSE,
  scale = TRUE,
  legend = TRUE
)
```

**Arguments**

|         |  |
|---------|--|
| object  | a trained <a href="#">MOFA</a> object.   |
| factors | a vector of length two with the factors to plot. Factors can be specified either as a characters using the factor names, or as numeric with the index of the factors |

|                           |  |
|---------------------------|--|
| <code>view</code>         | character vector with the view name, or numeric vector with the index of the view to use. Default is the first view.   |
| <code>color_by</code>     | specifies groups or values used to color the features. This can be either <ul style="list-style-type: none"><li>• a character giving the name of a column in the feature metadata slot</li><li>• a vector specifying the value for each feature.</li><li>• a dataframe with two columns: "feature" and "color"</li></ul> |
| <code>shape_by</code>     | specifies groups or values used to shape the features. This can be either <ul style="list-style-type: none"><li>• a character giving the name of a column in the feature metadata slot</li><li>• a vector specifying the value for each feature.</li><li>• a dataframe with two columns: "feature" and "shape"</li></ul> |
| <code>dot_size</code>     | numeric indicating dot size.   |
| <code>name_color</code>   | name for color legend (usually only used if <code>color_by</code> is not a character itself)   |
| <code>name_shape</code>   | name for shape legend (usually only used if <code>shape_by</code> is not a character itself)   |
| <code>show_missing</code> | logical indicating whether to include dots for which <code>shape_by</code> or <code>color_by</code> is missing   |
| <code>abs</code>          | logical indicating whether to take the absolute value of the weights.  |
| <code>scale</code>        | logical indicating whether to scale all weights from -1 to 1 (or from 0 to 1 if <code>abs=TRUE</code> ).   |
| <code>legend</code>       | logical indicating whether to add a legend to the plot (default is <code>TRUE</code> ).  |

### Details

One of the first steps for the annotation of factors is to visualise and group/color them using known covariates such as phenotypic or clinical data. This method generates a single scatterplot for the combination of two latent factors.

### Value

Returns a `ggplot2` object

### Examples

```
# Using an existing trained model on simulated data
file <- system.file("extdata", "model.hdf5", package = "MOFA2")
model <- load_model(file)
plot_weights_scatter(model, factors = 1:2)
```

---

predict *Do predictions using a fitted MOFA*

---

### Description

This function uses the latent factors and the weights to do data predictions.

### Usage

```
predict(  
  object,  
  views = "all",  
  groups = "all",  
  factors = "all",  
  add_intercept = TRUE  
)
```

### Arguments

|               |   |
|---------------|---|
| object        | a <a href="#">MOFA</a> object.  |
| views         | character vector with the view name(s), or numeric vector with the view index(es). Default is "all".    |
| groups        | character vector with the group name(s), or numeric vector with the group index(es). Default is "all".  |
| factors       | character vector with the factor name(s) or numeric vector with the factor index(es). Default is "all". |
| add_intercept | add feature intercepts to the prediction (default is TRUE).   |

### Details

MOFA generates a denoised and condensed low-dimensional representation of the data that captures the main sources of heterogeneity of the data. This representation can be used to reconstruct a denoised representation of the data, simply using the equation  $Y = WX$ . For more mathematical details read the supplementary methods of the manuscript.

### Value

Returns a list with the data reconstructed by the model predictions.

### Examples

```
# Using an existing trained model on simulated data  
file <- system.file("extdata", "model.hdf5", package = "MOFA2")  
model <- load_model(file)  
  
# Predict observations for all data modalities  
predictions <- predict(model)
```

---

|              |                                    |
|--------------|------------------------------------|
| prepare_mofa | <i>Prepare a MOFA for training</i> |
|--------------|------------------------------------|

---

## Description

Function to prepare a [MOFA](#) object for training. It requires defining data, model and training options.

## Usage

```
prepare_mofa(  
  object,  
  data_options = NULL,  
  model_options = NULL,  
  training_options = NULL,  
  stochastic_options = NULL,  
  mefisto_options = NULL  
)
```

## Arguments

|                    |   |
|--------------------|---|
| object             | an untrained <a href="#">MOFA</a>   |
| data_options       | list of data_options (see <a href="#">get_default_data_options</a> details). If NULL, default options are used.   |
| model_options      | list of model options (see <a href="#">get_default_model_options</a> for details). If NULL, default options are used.                                     |
| training_options   | list of training options (see <a href="#">get_default_training_options</a> for details). If NULL, default options are used.                               |
| stochastic_options | list of options for stochastic variational inference (see <a href="#">get_default_stochastic_options</a> for details). If NULL, default options are used. |
| mefisto_options    | list of options for mefisto (see <a href="#">get_default_mefisto_options</a> for details). If NULL, default options are used.                             |

## Details

This function is called after creating a [MOFA](#) object (using [create\\_mofa](#)) and before starting the training (using [run\\_mofa](#)). Here, we can specify different options for the data (`data_options`), the model (`model_options`) and the training (`training_options`, `stochastic_options`). Take a look at the individual default options for an overview using the `get_default_XXX_options` functions above.

## Value

Returns an untrained [MOFA](#) with specified options filled in the corresponding slots

## Examples

```
# Using an existing simulated data with two groups and two views
file <- system.file("extdata", "test_data.RData", package = "MOFA2")

# Load data dt (in data.frame format)
load(file)

# Create the MOFA object
MOFAmodel <- create_mofa(dt)

# Prepare MOFA object using default options
MOFAmodel <- prepare_mofa(MOFAmodel)

# Prepare MOFA object changing some of the default model options values
model_opts <- get_default_model_options(MOFAmodel)
model_opts$num_factors <- 10
MOFAmodel <- prepare_mofa(MOFAmodel, model_options = model_opts)
```

---

run\_enrichment

*Run feature set Enrichment Analysis*

---

## Description

Method to perform feature set enrichment analysis. Here we use a slightly modified version of the [pcgse](#) function.

## Usage

```
run_enrichment(
  object,
  view,
  feature.sets,
  factors = "all",
  set.statistic = c("mean.diff", "rank.sum"),
  statistical.test = c("parametric", "cor.adj.parametric", "permutation"),
  sign = c("all", "positive", "negative"),
  min.size = 10,
  nperm = 1000,
  p.adj.method = "BH",
  alpha = 0.1,
  verbose = TRUE
)
```

## Arguments

|        |  |
|--------|--|
| object | a <a href="#">MOFA</a> object.   |
| view   | a character with the view name, or a numeric vector with the index of the view to use. |

|                               |   |
|-------------------------------|---|
| <code>feature.sets</code>     | data structure that holds feature set membership information. Must be a binary membership matrix (rows are feature sets and columns are features). See details below for some pre-built gene set matrices.          |
| <code>factors</code>          | character vector with the factor names, or numeric vector with the index of the factors for which to perform the enrichment.  |
| <code>set.statistic</code>    | the set statistic computed from the feature statistics. Must be one of the following: "mean.diff" (default) or "rank.sum".  |
| <code>statistical.test</code> | the statistical test used to compute the significance of the feature set statistics under a competitive null hypothesis. Must be one of the following: "parametric" (default), "cor.adj.parametric", "permutation". |
| <code>sign</code>             | use only "positive" or "negative" weights. Default is "all".  |
| <code>min.size</code>         | Minimum size of a feature set (default is 10).  |
| <code>nperm</code>            | number of permutations. Only relevant if <code>statistical.test</code> is set to "permutation". Default is 1000   |
| <code>p.adj.method</code>     | Method to adjust p-values factor-wise for multiple testing. Can be any method in <code>p.adjust.methods()</code> . Default uses Benjamini-Hochberg procedure.   |
| <code>alpha</code>            | FDR threshold to generate lists of significant pathways. Default is 0.1   |
| <code>verbose</code>          | boolean indicating whether to print messages on progress  |

## Details

The aim of this function is to relate each factor to pre-defined biological pathways by performing a gene set enrichment analysis on the feature weights.

This function is particularly useful when a factor is difficult to characterise based only on the genes with the highest weight.

We provide a few pre-built gene set matrices in the MOFAdata package. See <https://github.com/bioFAM/MOFAdata> for details.

The function we implemented is based on the [pcgse](#) function with some modifications. Please read this paper <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4543476> for details on the math.

## Value

a list with five elements:

|                            |  |
|----------------------------|--|
| <b>pval:</b>               | matrices with nominal p-values.                      |
| <b>pval.adj:</b>           | matrices with FDR-adjusted p-values.                 |
| <b>feature.statistics:</b> | matrices with the local (feature-wise) statistics.   |
| <b>set.statistics:</b>     | matrices with the global (gene set-wise) statistics. |
| <b>sigPathways</b>         | list with significant pathways per factor.           |



---

|          |                           |
|----------|---------------------------|
| run_mofa | <i>Train a MOFA model</i> |
|----------|---------------------------|

---

## Description

Function to train an untrained [MOFA](#) object.

## Usage

```
run_mofa(object, outfile = NULL, save_data = TRUE, use_basilisk = FALSE)
```

## Arguments

|              |   |
|--------------|---|
| object       | an untrained <a href="#">MOFA</a> object  |
| outfile      | output file for the model (.hdf5 format). If NULL, a temporary file is created.   |
| save_data    | logical indicating whether to save the training data in the hdf5 file. This is useful for some downstream analysis (mainly functions with the prefix <code>plot_data</code> ), but it can take a lot of disk space.   |
| use_basilisk | use basilisk to automatically install a conda environment with mofapy2 and all dependencies? If FALSE (default), you should specify the right python binary when loading R with <code>reticulate::use_python(..., force=TRUE)</code> or the right conda environment with <code>reticulate::use_condaenv(..., force=TRUE)</code> . |

## Details

This function is called once a MOFA object has been prepared (using [prepare\\_mofa](#)) In this step the R package calls the mofapy2 Python package, where model training is performed.

The interface with Python is done with the [reticulate](#) package. If you have several versions of Python installed and R is not detecting the correct one, you can change it using `reticulate::use_python` when loading the R session. Alternatively, you can let us install mofapy2 for you using basilisk if you set `use_basilisk` to TRUE

## Value

a trained [MOFA](#) object

## Examples

```
# Load data (in data.frame format)
file <- system.file("extdata", "test_data.RData", package = "MOFA2")
load(file)

# Create the MOFA object
MOFAmodel <- create_mofa(dt)

# Prepare the MOFA object with default options
MOFAmodel <- prepare_mofa(MOFAmodel)
```

```
# Run the MOFA model
## Not run: MOFAmodel <- run_mofa(MOFAmodel, use_basilisk = TRUE)
```

---

```
run_tsne          Run t-SNE on the MOFA factors
```

---

## Description

Run t-SNE on the MOFA factors

## Usage

```
run_tsne(object, factors = "all", groups = "all", ...)
```

## Arguments

|         |   |
|---------|---|
| object  | a trained <a href="#">MOFA</a> object.  |
| factors | character vector with the factor names, or numeric vector with the indices of the factors to use, or "all" to use all factors (default).          |
| groups  | character vector with the groups names, or numeric vector with the indices of the groups of samples to use, or "all" to use all groups (default). |
| ...     | arguments passed to <a href="#">Rtsne</a>   |

## Details

This function calls [Rtsne](#) to calculate a TSNE representation from the MOFA factors. Subsequently, you can plot the TSNE representation with [plot\\_dimred](#) or fetch the coordinates using `plot_dimred(..., method="TSNE", return_data=TRUE)`. Remember to use `set.seed` before the function call to get reproducible results.

## Value

Returns a [MOFA](#) object with the `MOFAobject@dim_red` slot filled with the t-SNE output

## Examples

```
# Using an existing trained model on simulated data
file <- system.file("extdata", "model.hdf5", package = "MOFA2")
model <- load_model(file)

# Run
## Not run: model <- run_tsne(model, perplexity = 15)

# Plot
## Not run: model <- plot_dimred(model, method="TSNE")

# Fetch data
## Not run: tsne.df <- plot_dimred(model, method="TSNE", return_data=TRUE)
```

---

|          |                                     |
|----------|-------------------------------------|
| run_umap | <i>Run UMAP on the MOFA factors</i> |
|----------|-------------------------------------|

---

### Description

Run UMAP on the MOFA factors

### Usage

```
run_umap(  
  object,  
  factors = "all",  
  groups = "all",  
  n_neighbors = 30,  
  min_dist = 0.3,  
  metric = "cosine",  
  ...  
)
```

### Arguments

|             |  |
|-------------|--|
| object      | a trained <a href="#">MOFA</a> object.   |
| factors     | character vector with the factor names, or numeric vector with the indices of the factors to use, or "all" to use all factors (default).   |
| groups      | character vector with the groups names, or numeric vector with the indices of the groups of samples to use, or "all" to use all groups (default).  |
| n_neighbors | number of neighboring points used in local approximations of manifold structure. Larger values will result in more global structure being preserved at the loss of detailed local structure. In general this parameter should often be in the range 5 to 50.                                     |
| min_dist    | This controls how tightly the embedding is allowed compress points together. Larger values ensure embedded points are more evenly distributed, while smaller values allow the algorithm to optimise more accurately with regard to local structure. Sensible values are in the range 0.01 to 0.5 |
| metric      | choice of metric used to measure distance in the input space   |
| ...         | arguments passed to <a href="#">umap</a>   |

### Details

This function calls [umap](#) to calculate a UMAP representation from the MOFA factors For details on the hyperparameters of UMAP see the documentation of [umap](#). Subsequently, you can plot the UMAP representation with [plot\\_dimred](#) or fetch the coordinates using `plot_dimred(..., method="UMAP", return_data=TRUE)`. Remember to use `set.seed` before the function call to get reproducible results.

**Value**

Returns a [MOFA](#) object with the `MOFAobject@dim_red` slot filled with the UMAP output

**Examples**

```
# Using an existing trained model on simulated data
file <- system.file("extdata", "model.hdf5", package = "MOFA2")
model <- load_model(file)

# Change hyperparameters passed to umap
## Not run: model <- run_umap(model, min_dist = 0.01, n_neighbors = 10)
# Plot
## Not run: model <- plot_dimred(model, method="UMAP")

# Fetch data
## Not run: umap.df <- plot_dimred(model, method="UMAP", return_data=TRUE)
```

---

|                               |   |
|-------------------------------|---|
| <code>samples_metadata</code> | <i>samples_metadata: retrieve sample metadata</i> |
|-------------------------------|---|

---

**Description**

`samples_metadata`: retrieve sample metadata

**Usage**

```
samples_metadata(object)

samples_metadata(object) <- value

## S4 method for signature 'MOFA'
samples_metadata(object)

## S4 replacement method for signature 'MOFA,data.frame'
samples_metadata(object) <- value
```

**Arguments**

|                     |   |
|---------------------|---|
| <code>object</code> | a <a href="#">MOFA</a> object.  |
| <code>value</code>  | data frame with sample metadata, it must at least contain the columns <code>sample</code> and <code>group</code> . The order of the rows must match the order of <code>samples_names(object)</code> |

**Value**

a data frame with sample metadata

## Examples

```
# Using an existing trained model on simulated data
file <- system.file("extdata", "model.hdf5", package = "MOFA2")
model <- load_model(file)
samples_metadata(model)
```

---

|               |   |
|---------------|---|
| samples_names | <i>samples_names: set and retrieve sample names</i> |
|---------------|---|

---

## Description

samples\_names: set and retrieve sample names

## Usage

```
samples_names(object)

samples_names(object) <- value

## S4 method for signature 'MOFA'
samples_names(object)

## S4 replacement method for signature 'MOFA,list'
samples_names(object) <- value
```

## Arguments

|        |   |
|--------|---|
| object | a <a href="#">MOFA</a> object.                                  |
| value  | list of character vectors with the sample names for every group |

## Value

list of character vectors with the sample names for each group

## Examples

```
# Using an existing trained model on simulated data
file <- system.file("extdata", "model.hdf5", package = "MOFA2")
model <- load_model(file)
samples_names(model)
```

---

|              |  |
|--------------|--|
| select_model | <i>Select a model from a list of trained MOFA objects based on the best ELBO value</i> |
|--------------|--|

---

### Description

Different objects of MOFA are compared in terms of the final value of the ELBO statistics and the model with the highest ELBO value is selected.

### Usage

```
select_model(models, plot = FALSE)
```

### Arguments

|        |   |
|--------|---|
| models | a list containing MOFA objects.   |
| plot   | boolean indicating whether to show a plot of the ELBO for each model instance |

### Value

A MOFA object

---

|                |                                       |
|----------------|---------------------------------------|
| set_covariates | <i>Add covariates to a MOFA model</i> |
|----------------|---------------------------------------|

---

### Description

Function to add continuous covariate(s) to a MOFA object for training with MEFISTO

### Usage

```
set_covariates(object, covariates)
```

### Arguments

|            |   |
|------------|---|
| object     | an untrained MOFA   |
| covariates | Sample-covariates to be passed to the model. This can be either: <ul style="list-style-type: none"> <li>• a character, specifying columns already present in the samples_metadata of the object</li> <li>• a data.frame with columns "sample", "covariate", "value". Sample names need to match those present in the data</li> <li>• a matrix with samples in columns and covariate(s) in row(s)</li> </ul> |

Note that the covariate should be numeric and continuous.

**Details**

To activate the functional MEFISTO framework, specify `mefisto_options` when preparing the training using `prepare_mofa`

**Value**

Returns an untrained [MOFA](#) with covariates filled in the corresponding slots

**Examples**

```
#' # Simulate data
dd <- make_example_data(sample_cov = seq(0,1,length.out = 100), n_samples = 100, n_factors = 4)

# Create MOFA object
sm <- create_mofa(data = dd$data)

# Add a covariate
sm <- set_covariates(sm, covariates = dd$sample_cov)
sm
```

---

|                |                       |
|----------------|-----------------------|
| subset_factors | <i>Subset factors</i> |
|----------------|-----------------------|

---

**Description**

Method to subset (or sort) factors

**Usage**

```
subset_factors(object, factors, recalculate_variance_explained = TRUE)
```

**Arguments**

|   |  |
|---|--|
| <code>object</code>                         | a <a href="#">MOFA</a> object.   |
| <code>factors</code>                        | character vector with the factor names, or numeric vector with the index of the factors. |
| <code>recalculate_variance_explained</code> | logical indicating whether to recalculate variance explained values. Default is TRUE.    |

**Value**

A [MOFA](#) object

**Examples**

```
# Using an existing trained model on simulated data
file <- system.file("extdata", "model.hdf5", package = "MOFA2")
model <- load_model(file)

# Subset factors 1 to 3
model <- subset_factors(model, factors = 1:3)
```

---

|                 |                        |
|-----------------|------------------------|
| subset_features | <i>Subset features</i> |
|-----------------|------------------------|

---

**Description**

Method to subset (or sort) features

**Usage**

```
subset_features(object, view, features)
```

**Arguments**

|          |  |
|----------|--|
| object   | a <a href="#">MOFA</a> object.   |
| view     | character vector with the view name or integer with the view index   |
| features | character vector with the sample names, numeric vector with the feature indices or logical vector with the samples to be kept as TRUE. |

**Value**

A [MOFA](#) object

---

|               |                      |
|---------------|----------------------|
| subset_groups | <i>Subset groups</i> |
|---------------|----------------------|

---

**Description**

Method to subset (or sort) groups

**Usage**

```
subset_groups(object, groups)
```

**Arguments**

|        |  |
|--------|--|
| object | a <a href="#">MOFA</a> object.   |
| groups | character vector with the groups names, numeric vector with the groups indices or logical vector with the groups to be kept as TRUE. |



**Value**

A MOFA object

**Examples**

```
# Using an existing trained model on simulated data
file <- system.file("extdata", "model.hdf5", package = "MOFA2")
model <- load_model(file)

# Subset the first group
model <- subset_groups(model, groups = 1)
```

---

|                |                       |
|----------------|-----------------------|
| subset_samples | <i>Subset samples</i> |
|----------------|-----------------------|

---

**Description**

Method to subset (or sort) samples

**Usage**

```
subset_samples(object, samples)
```

**Arguments**

|         |   |
|---------|---|
| object  | a MOFA object.  |
| samples | character vector with the sample names or numeric vector with the sample indices. |

**Value**

A MOFA object

**Examples**

```
# Using an existing trained model on simulated data
file <- system.file("extdata", "model.hdf5", package = "MOFA2")
model <- load_model(file)

# (T0-D0) Remove a specific sample from the model (an outlier)
```

---

|              |                     |
|--------------|---------------------|
| subset_views | <i>Subset views</i> |
|--------------|---------------------|

---

**Description**

Method to subset (or sort) views

**Usage**

```
subset_views(object, views)
```

**Arguments**

|        |  |
|--------|--|
| object | a <a href="#">MOFA</a> object.   |
| views  | character vector with the views names, numeric vector with the views indices, or logical vector with the views to be kept as TRUE. |

**Value**

A [MOFA](#) object

**Examples**

```
# Using an existing trained model on simulated data
file <- system.file("extdata", "model.hdf5", package = "MOFA2")
model <- load_model(file)

# Subset the first view
model <- subset_views(model, views = 1)
```

---

|                   |  |
|-------------------|--|
| summarise_factors | <i>Summarise factor values using external groups</i> |
|-------------------|--|

---

**Description**

Function to summarise factor values using a discrete grouping of samples.

**Usage**

```
summarise_factors(
  object,
  df,
  factors = "all",
  groups = "all",
  abs = FALSE,
  return_data = FALSE
)
```

**Arguments**

|             |  |
|-------------|--|
| object      | a trained <a href="#">MOFA</a> object.   |
| df          | a data.frame with the columns "sample" and "level", where level is a factor with discrete group assignments for each sample.                         |
| factors     | character vector with the factor name(s), or numeric vector with the index of the factor(s) to use. Default is 'all'.                                |
| groups      | character vector with the groups names, or numeric vector with the indices of the groups of samples to use, or "all" to use samples from all groups. |
| abs         | logical indicating whether to take the absolute value of the factors (default is FALSE).   |
| return_data | logical indicating whether to return the fa instead of plotting  |

**Value**

A [ggplot](#) object or a data.frame if return\_data is TRUE

---

|             |   |
|-------------|---|
| views_names | <i>views_names: set and retrieve view names</i> |
|-------------|---|

---

**Description**

views\_names: set and retrieve view names

**Usage**

```
views_names(object)

views_names(object) <- value

## S4 method for signature 'MOFA'
views_names(object)

## S4 replacement method for signature 'MOFA,character'
views_names(object) <- value
```

**Arguments**

|        |   |
|--------|---|
| object | a <a href="#">MOFA</a> object.                |
| value  | character vector with the names for each view |

**Value**

character vector with the names for each view

## Examples

```
# Using an existing trained model on simulated data
file <- system.file("extdata", "model.hdf5", package = "MOFA2")
model <- load_model(file)
views_names(model)
views_names(model) <- c("viewA", "viewB")
```

---

%>% *Re-exporting the pipe operator See [magrittr::Rpercent>Rpercent](#) for details.*

---

## Description

Re-exporting the pipe operator See [magrittr::%>%](#) for details.

## Usage

```
lhs %>% rhs
```

## Arguments

|     |                                      |
|-----|--------------------------------------|
| lhs | see <a href="#">magrittr::%&gt;%</a> |
| rhs | see <a href="#">magrittr::%&gt;%</a> |

## Value

depending on lhs and rhs

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